Impact of School-based Blood Lead Surveillance on the Identification, Screening, and Referral Rates of at-Risk Children

DNP Final Project

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By

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Dedication

This project is dedicated to Gigi. You always supported and encouraged me when I needed it most and guided me through this process. You were there every step of the way. I love and miss you every day and will continue to move forward with your strength as my guide.

Abstract

Background: Elevated blood lead levels in young children (ages 1 to 6 years) continues to be a public health priority. Blood lead levels that to exceed public health recommendations (5 µ/dL), and those as low as 1 to 2 µ/dL, have negative effects on a child's neurological development and subsequent achievement in school. School nurses are experts in public health and improve health and academic outcomes of children in at-risk geographical areas. Improving screening, evaluation, and referral of elevated blood lead levels at the school level is essential in protecting the development of children.

Objectives: The purpose of this project was to evaluate and improve on the effectiveness of blood lead level monitoring and student referral using an evidence-based school nurse approach to improve the identification and referral of school-aged children with lead exposure. Through the implementation of an evidence-based public health surveillance tool (Impact SIIS), school nurses may improve health and academic outcomes of children in at-risk geographical areas.

Methods: The CDC's "Decision Chart for Students Affected by Lead" was modified to guide school nursing practice in two Ohio schools located in high-risk areas for elevated lead levels. The nurse from each school completed a baseline audit of school health records to determine if blood lead levels were routinely reported in school health physicals, immunization reports previously printed from Impact SIIS, or communicated with the school by other means.

Results: Results of the baseline audit indicated blood lead screening results were not routinely available in school health records. Baseline results indicated that 0-2.4% of student health records contained blood lead screening results for students in grades Kindergarten to 3. The results of the intervention audit indicated school-based blood lead surveillance, utilizing Impact SIIS, increased the identification of blood lead screening results, for students in grades Kindergarten to 3, to 59% in School B and 100% for School A. The students in School B who did not have a blood lead result were referred for screening.

Conclusion: Impact SIIS was an effective tool for performing school-based blood lead surveillance in schools. The Modified Decision Chart guided school nurses through the referral of students, according to the blood lead screening results identified. Students were referred for screening, monitoring, or Child Find and Health Department. The Modified Decision Chart was effective in guiding the identification and referral of students with elevated lead levels and screening for those without lead level results.

Keywords: blood lead screening, school-based surveillance, blood lead levels, CDC Decision Chart for Student Affected by Lead, Impact SIIS

Section One: Nature of the Problem

Introduction to the problem

Elevated blood lead levels (EBLL) in children ages 1 to 6 years continues to be a public health priority, despite decades of surveillance and intervention. Progress has been shown in the overall percentage of children with identified EBLL, but the percentage of children screened is not occurring at recommended age levels (Jones et al., 2009; AAP, 2016; Lanphear, 2005). Children at risk for chronic low-level lead exposure are not identified for intervention, as they fall below the national reference value of 5 micrograms (µ)/dL (Meyer et al., 2003). Blood lead levels as low as 1 to 2 µ/dL can have negative impacts on a child's neurological development and subsequent achievement in school. These impacts include behavior problems, sensory integration deficits, attention deficits, decreased IQ, and difficulty achieving in school (Ness, 2013; AAP, 2016; Raymond & Brown, 2017; Lanphear, 2005).

The current Centers for Disease Control and Prevention (CDC) guidelines for blood lead screening include screening all children between the age of 12 and 24 months and all children up to 72 months of age, without previous blood lead level screening (CDC, 2012; Ness, 2013). There are health disparities related to the exposure, screening, and identification of children with lead exposure. Increased exposure and chronic low-level exposures to lead are typically seen in children living in older homes, lower socioeconomic status, and non-Hispanic black populations (White, Shaw-Bonilha, & Ellis, 2016). The Centers for Disease Control (CDC) currently estimates children in at least 4 million US households are being exposed to high levels of lead on a daily basis (CDC, 2013). Nationwide, there are approximately 535,000 children between the age of 1 and 5 years with BLL greater than the national reference value of 5 µ/dL (CDC, 2013; AAP, 2016). Less than half of all Medicaid eligible children are appropriately screened for lead (Raymond, Wheeler, & Brown, 2014; AAP, 2016; Raymond & Brown, 2017; Pell & Schneyer, 2016), despite the requirement that all children ages 12 to 24 months, enrolled in Medicaid, undergo mandatory blood lead screening.

The Centers for Medicare and Medicaid Services (CMS) provides state-specific data related to annual Early and Periodic Screening, Diagnostic and Treatment (EPSDT) participation reports. Medicaid regulations provide EPSDT benefits to all children under age 21 years. The EPSDT benefits include both prevention and treatment services, including blood lead screening (CMS, 2019b). Table 1.1 outlines the CMS data related to blood lead screening provided under EPSDT services for 2017. The overall BLL screening rate for Medicaid-eligible children ages 0-5 years, for 2017, was 21.7% in Ohio and 14.9% nationally, but rate for 1-2 year olds was 42.5% and 42.8%, respectively (CMS, 2019a). The Ohio Department of Health (ODH) estimated 3.7 million Ohio households, 42% of all housing units statewide, contain lead hazards (Children's Defense Fund of Ohio, 2019). Approximately 3% of all Ohio children 0-5 years old tested had confirmed BLL equal to or greater than 5 μ/dL, however, only approximately 40% of the Ohio's at-risk children are screened yearly for lead (Children's Defense Fund of Ohio, 2019).

Table 1.1 Medicaid Status and BLL Screening (CMS, 2019a)

Medicaid Status	National 2017	Ohio 2017	Blood Lead Screening Rate 2017	
			National	Ohio
Total Medicaid Eligible ages birth-5 years	21,052,441	491,270		
Total number Blood Lead screens	3,129,929	10,6479		
Total Medicaid Eligible <1 year	2,340,636	79,567		
Blood Lead screens <1 year		1,073	2.5%	1.3%
Total Medicaid Eligible 1-2 years	4,831,378	169,440		
Blood Lead screens 1-2 years		72,028	42.8%	42.5%
Total Medicaid Eligible 3-5 years	6,708,413	242,263		
Blood Lead screens 3-5 years		33,378	14.9%	13.8%

School nurses perform school-based surveillance for immunizations on a yearly basis to meet state-mandated health appraisal requirements. This surveillance includes gathering health data from health history and physical forms, paper immunization records, and the state immunization registry, Impact SIIS. Access and utilization of Impact SIIS has greatly increased the efficiency and effectiveness of the immunization surveillance programs in Ohio schools. Since its introduction as a tool for school nurses, Impact SIIS has led to an immunization completion rate of approximately 92% for Ohio schools (CDC, 2017). Due to its effectiveness, Impact SIIS now additional health appraisal data, including blood lead levels. If Impact SIIS is an effective tool for school-based immunization surveillance, can it also be utilized as an effective means of school-based blood lead surveillance? If the Ohio Department of Health (ODH) utilizes the blood lead level results in Impact SIIS to monitor aggregate results, can school-based surveillance be utilized to monitor individual results, including the blood lead results of those children falling under the current intervention threshold of 5 µ/dL?

Recommendations for local educational agencies, or schools, were released by CDC to ensure children affected by lead exposure were identified, assessed, and received appropriate services (CDC, 2015). The CDC's "Decision Chart for Children Affected by Lead" is an algorithm guiding schools through this process (Appendix A). The advantage to this algorithm is the identification of children without recorded blood lead levels, who would benefit from BLL screening, while also identifying the children with low- and high-level lead exposure. This increases the ability of school nurses and school intervention teams to improve the screening and identification of children at risk for difficulties in academic achievement related to lead exposure.

Purpose of the Project

This purpose of this project is to improve the identification and referral of school-aged children with lead exposure in the school setting. A specific aim of the project is to determine the effectiveness of using Impact SIIS, an evidence-based public health tool, to improve health and academic outcomes of children in at-risk geographical areas.

Client/Population. The population, students and schools, represented geographic areas known to have high rates of lead exposure. ODH data indicate Richland and Ashland counties contain three high-risk geographical areas for lead exposure: Mansfield, Ashland, and Loudonville (ODH, 2016a; ODH, 2016b). The ODH predicted prevalence rates of blood lead levels (BLL) above 5 µ/dL is elevated in Mansfield (Richland County) (≥ 27.3%) and Ashland and Loudonville (Ashland County) (11.5%-18.2%) (ODH, 2016a; ODH, 2016b). Richland County screened 1526 children under 72 months of age, with (94.6% (n=1443)) with BLL under 5 µ/dL and (5.4% (n=83)) over 5 µ/dL (ODH, 2017). Ashland County screened 524 children under 72 months of age, with (96.4% (n=505)) with BLL under 5 µ/dL and (3.6% (n=19)) over 5 µ/dL (ODH, 2017). ODH data suggest there are increased numbers of children with BLL less than 5 µ/dL identified in aggregate screening data (ODH, 2018). Appendix B and C represent a pictorial representation of the predicted prevalence of BLL in Ashland and Richland counties in Ohio.

Patient population preferences and overall values. The patient population represented students from two elementary schools in Ashland and Richland counties of north-central Ohio. These students, Kindergarten through Grade 3, represent a cross-section of the school-age population of this geographical area. The majority of students live in older homes, either in rural or inner city surroundings, and 17- 20% of all students live below the poverty level. The elementary schools chosen represent the high-risk zip code areas of the counties. These areas would require blood lead testing for all children under the age of 6 years. A third elementary school was identified; however, they were unable to participate in the period provided.

The majority of healthcare services are provided by the Ashland or Richland county health departments, locally federally qualified medical clinics, or hospital-affiliated regional satellite offices. The uninsured population in each county is 7%, but the ratio of Primary Care Physicians (PCP) to the overall population is 1:1,920 in Ashland County and 1:1,860 in Richland County. Richland County's ratio is slightly better than Ashland County's, but both counties ratios are larger than the ratio for Ohio, 1:1,300. Richland's population has a higher percentage of non-Hispanic blacks, greater overall population in poverty, and higher percentage yearly family mobility, lower graduation rate, and lower mean household income than Ashland County.

The demographics of the patient population and communities are represented in Tables 2.1 and 2.2.

Table 2.1 Demographics by County (RWJF, 2019; U.S. Census Bureau, 2017)

Demographics			
County	Richland	Ashland	Ohio
Racial makeup			
White	87.3%	97%	82.2%
Hispanic	1.9%	1.4%	3.8%
Non-Hispanic black	9.4%	0.8%	12.9%
Asian, Am Indian, Pacific Island, other	1%	0.9%	2.7%
Estimated Population	120,589	53,628	11,658,609
Population in poverty	13.4%	11.4%	14%
Children<5 years	5.8%	5.9%	6%
Children in poverty	20%	17%	20%
Uninsured	7%	7%	7%
Primary Care Physicians Ratio	1:1,860	1:1,920	1:1,300
HS Graduation	90%	94%	85%
Unemployment	5.5%	4.9%	5%
Children in single-parent households	35%	25%	36%
Living in same house 1 year ago	83.3%	85.4%	85.1%
Mean Household Income	$44,138	$50,893	$52,407

Table 2.2 Demographics by School District (Mansfield City Schools, 2018; Ashland City Schools, 2018)

Demographics	Mansfield City Schools	Ashland City Schools
County	Richland	Ashland
Municipality type	Metropolitan	City
School district enrollment K-12	4500	3700

According to the most recent Area Deprivation Index (ADI) and Robert Wood Johnson Foundation (RWJF) County Health Rankings, Ashland and Mansfield represent areas of disadvantaged populations. This graphic representation in Figure 2.1 supports the demographics discussed and displayed in Table 2.1, Richland County has a higher proportion of the county represented in the 8-10 range.

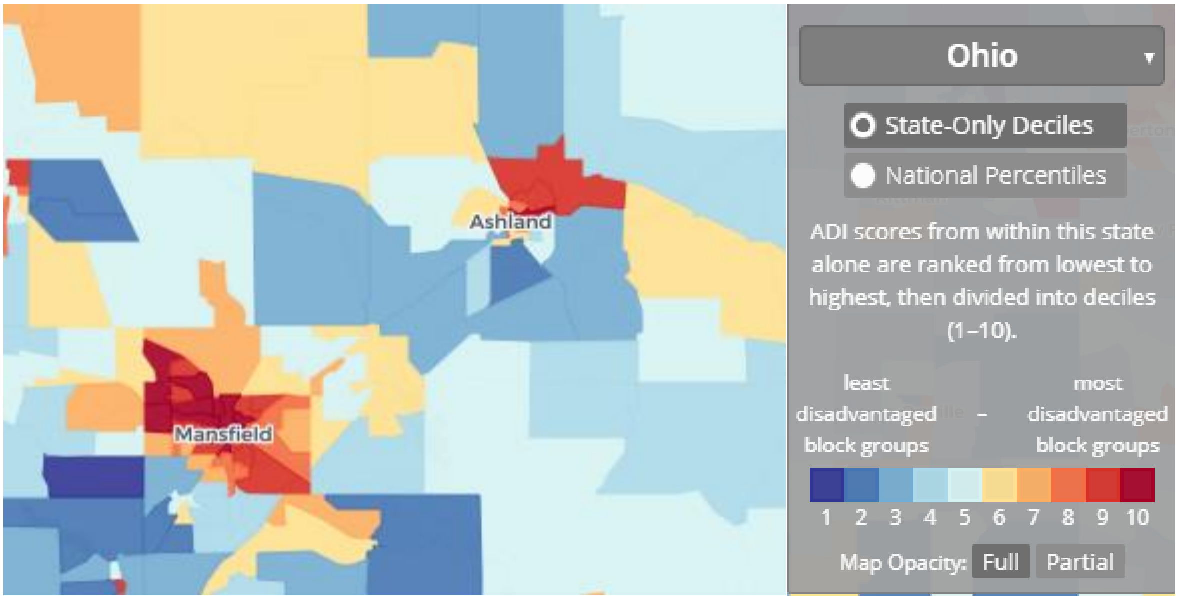

Figure 2.1 ADI Neighborhood Atlas (University of Wisconsin School of Medicine and Public Health, 2018)

The RWJF County Health Rankings identify a variety of measures affecting the overall health of communities. Health outcomes differ in respect to where individuals live and their ethnic/racial group. Historically, there have been fewer resources and opportunities for better health among people of color and those living in poverty (RWJF, 2019). Achieving health equity requires reducing and eliminating these differences in living conditions and access to appropriate resources and opportunities across communities. The County Health Rankings provide a numeric ranking for each of the counties in Ohio, with 1 indicating the best and 88 being the worst ranking. Figure 2.2 illustrates the rankings of Ashland and Richland counties. Overall, Ashland ranks higher in the rankings than Richland, and ranks within the top 25% of Ohio counties. Richland ranks within the lowest 30-25% of counties in Ohio for most measures. The demographics, ADI data, and County Health Rankings indicate Ashland and Richland counties are communities at-risk for health disparities related to the their geographic location.

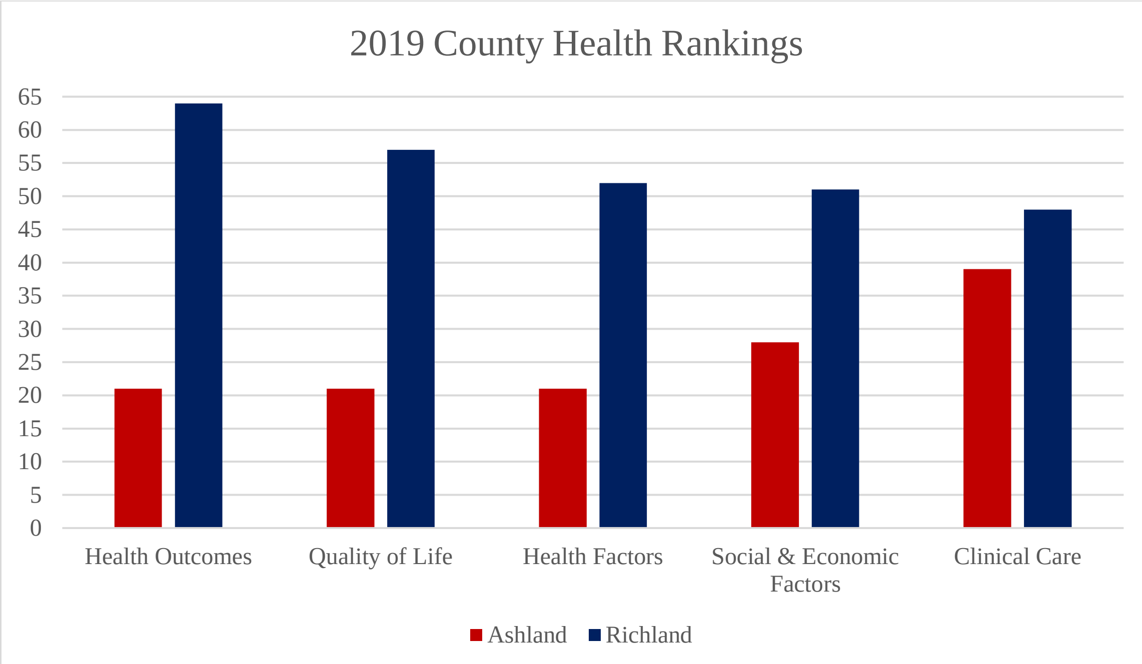

Figure 2.2 2019 County Health Rankings (RWJF, 2019)

The patient population included students in Kindergarten through Grade 3, rather than just up to 6 years of age. This allowed for a broader look at the overall screening rate for children in this area. The adverse educational effects related to math and reading are critical assessment points for Ohio school-aged children in Grade 3. It was beneficial to include students, up to and including Grade 3, to identify their past exposure to lead and utilize the Modified Decision Chart to facilitate early identification and management of these children in the school setting.

Section Two: Review of the Literature

Clinical Practice Problem Statement

Lead exposure in early childhood is a significant public health issue; recommendations are now focusing on the need for multidisciplinary, primary prevention efforts (Meyer et al., 2003; Lanphear et al., 2005; Bellinger & Bellinger, 2006; Jones et al., 2009; CDC,ACCLLP, 2012; Zhang et al., 2013; AAP, 2016; Lanphear, 2005). ODH data (2016a;2016b) suggests the 3 cities with the highest geographical risk in Ashland and Richland counties are Mansfield, Ashland, and Loudonville; increased numbers of children with blood level results $\geq$5 µg/dL; and numerous children with blood lead levels < 5 µg/dL identified in aggregate screening data. Current methods of blood lead surveillance do not effectively identify, screen, and refer children in the school setting for lead exposure. The PICOT question for this project is: In school-age children, how does school-based surveillance of blood lead screening results compared to current methods of surveillance affect the identification, screening, and referral of children with lead exposure in the school setting?

Evaluation/Summary of the Evidence from the Literature

The key words for the literature search were childhood, lead, lead poisoning, screening, blood lead, school-age children, and blood lead surveillance in children. Several databases were used for the literature search, including Cochrane Review, Cumulative Indexes to Nursing and Allied Health Literature (CINAHL), and PubMed. The parameters for the keyword searches were human, age (child), English language, and ranges from 5-10 years old. After the removal of duplicate records, the literature search resulted in 115 records, 77 were screened as eligible and 38 were excluded in the initial selection. The Rapid Critical Appraisal form from the Center for Transdisciplinary Evidence-based Practice was utilized for review of all articles. The evidence/summary table for the critical appraisal of evidence can be found in Appendix M.

Critical Appraisal of the Evidence

The scope of the problem for childhood lead exposure has been redefined over the past three decades. The challenge continues to be the screening and identification of children at risk for EBLL. States monitor BLLs on an aggregate level, but only children with EBLL are identified on an individual level; children with low-level lead exposure are not being identified or referred. Progress has been seen in the overall percentage of children with EBLL, but children, especially in high-risk populations, are still not being screened at recommended levels (Lanphear, 2005; Jones et al., 2009; AAP, 2016; CMS, 2019a). The CDC Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) last updated the lead screening guidelines in 2012. These updated guidelines reduced the national reference value from 10 to 5 μ/dL (CDC, ACCLPP, 2012; Ness, 201; Raymond & Brown, 20173). This reference value had been reduced from 25 to 10 μ/dL, in previous guideline updates and referred to as a threshold (CDC, 1992;

Lanphear, 2005). The common thread seen in the data since the Lead Contamination Control Act of 1988, a stepping-stone in prioritizing the public health issue of lead exposure in children, was the identification of children under the identified reference value experiencing adverse health effects from lead (CDC, 1992; Lanphear, 2005; CDC, 2013; AAP, 2016). This discovery prompted the use of reference value rather than threshold for subsequent guidelines.

There is no “safe” blood lead level (Meyer et al., 2003; Jones et al., 2009; Bellinger, 2008a; Bellinger, 2008b; Raymond & Brown, 2017). “Lead is a potent, pervasive neurotoxin and elevated blood lead levels can result in decreased IQ, academic failure, and behavioral problems in children” (Wengrovits & Brown, pp 1, 2009). Children process lead differently than adults and, as a result, lead has a higher volume of distribution in children. This means all organ systems are at risk for adverse effects, but the neurological system is at the greatest risk for harm. Adverse effects of lead occur regardless of route of exposure, typically absorbed through the GI or respiratory tracts (Ness, 2013). These adverse effects include vague health complaints, behavior problems, sensory integration deficits, attention deficits, decreased IQ, and difficulty achieving in school (Ness, 2013; ATSDR, 2017; Zhang et al., 2013; Needleman et al., 1979; Lanphear et al., 2005; AAP, 2016; Raymond & Brown, 2017). Only children with blood lead levels equal to or greater than 5 μ/dL are identified for referral; however, BLLs of as low as 1 to 2 μ/dL, can have negative impacts on a child’s neurological development and subsequent achievement in school (ATSDR, 2017; Ness, 2013; CDC, 2005; Meyer et al., 2003; AAP, 2016; Canfield, Kreher, Cornwell, & Henderson, 2004; Lanphear, Dietrich, Auinger, & Cox, 2000; Raymond & Brown, 2017).

Lead serves no purpose in the human body. Regardless of age, gender, or exposure pathway of exposure, lead is toxic (CDC, ACCLPP, 2012; Cecil et al., 2008; ATSDR, 2017; AAP, 2016; Bellinger, 2008a; Bellinger, 2008b;). Adverse child health outcomes of lead may be difficult to detect until they reach school age when academic outcomes are measured. The lack of overt symptoms does not mean no adverse impact. Lead inhibits the body from absorbing iron, zinc, and calcium. These minerals are essential for proper brain and nerve development. Developmental delays often include decreased IQ, reduced hearing, ADHD, sensory delays, fine motor delay, and aggression. Acute high-level lead exposure may result in encephalopathy, seizures, or death (ATSDR, 2017; NTP, 2012; Lanphear et al., 2002; AAP, 2016; Bellinger, 2008b; Raymond & Brown, 2017).

Childhood lead exposure also leads to adverse adult health outcomes. Health effects appear in the absence of current lead exposure because past exposures are accumulated in the bones. During times of stress, including pregnancy, the lead in bone demineralizes and enters the blood (ATSDR, 2017). Childhood lead exposure is associated with reductions in adult gray matter volume of the brain. The affected brain regions include those responsible for executive functions, mood regulation, and decision-making (Cecil et al., 2008).The long-term impact of childhood lead exposure can also be seen from generation to generation. In a retrospective study, a higher proportion of learning disabilities were found among school-aged children whose biological parents had lead poisoning as children (Hu, 1991). Molecular changes in the body's cells, especially neurons, occur by the replacement of calcium with lead. This cellular level change impacts the second-messenger systems within the cells and lead to changes in gene expression, or genetic changes (ATSDR, 2017). Past and current exposures to lead increase a person's risks for these adverse health effects.

Table 1.1 BLL and Adult Health Outcomes (NTP, 2012)

Childhood BLL	Adult Health Outcomes
<5 µg/dL	Reduced fetal growth or lower birth weight of future children Decreased renal function as an adult Reduced sperm count
<10 µg/dL	Decreased postnatal growth, including reduced head circumference, height, and Delayed puberty in children of adults with a history of childhood EBLL Increased blood pressure and hypertension
>10 µg/dL	Anemia Reduced fertility in women Decreased bone density

The socioeconomic and demographic factors associated with EBLL have well-established links to the social determinants of health (SDH), including housing, ethnicity, and poverty (Bernard & McGeehin, 2003; AAP, 2016). The at-risk population for EBLL includes non-Hispanic black children living in older homes (Bernard & McGeehin, 2003). The NHANES data from 1988-1994 indicated non-Hispanic black children were at three-times the risk of an EBLL between 5-10 μ/dL, seven-times the risk of an EBLL between 10-20 μ/dL, and thirteen-times the risk to have an EBLL over 20 μ/dL (Bernard & McGeehin, 2003).

An estimated 2.2 % (535,000) of all children, ages 1-5 years, have EBLLs (AAP, 2016; Meyer et al., 2003). From 1988 to 2004, data confirmed a general decline in EBLL, greater than or equal to 10 μ/dL, and overall decrease of 84% for children ages 1-5 years (Jones et al., 2009). Interventions attributed to this overall decline included identification of screening gaps in high-risk children, linking blood lead surveillance to Medicaid-eligibility, and environmental intervention in homes with more than one child identified with EBLL (Wengrovits & Brown, 2009). In spite of this overall decrease, non-Hispanic black children were still at greatest risk for EBLL among all subpopulations of children (Jones et al., 2009). Additional risk factors for EBLL also included living in older homes, lower socioeconomic status, and younger age. Linking Medicaid-eligibility to blood lead screening guidelines led to an increase in screening of approximately 25%, between the 1988-1991 and 1999-2004 NHANES study, for children ages 1 to 5 years (Jones et al., 2009). Data also indicated the overall decrease in EBLL was seen across all populations of children, including the high-risk Medicaid-eligible subpopulation (Wengrovitz & Brown, 2009; AAP, 2016).

The CDC released updated screening guidelines in 2012. The updated guidelines provided a new focus on the healthcare provider as partner in the prevention of lead poisoning, rather than just a responder to EBLL. The BLL reference value was decreased to equal the 97.5 percentile or 5 μ/dL (CDC, ACCLPP, 2012; Ness, 2013; AAP, 2016). Healthcare providers should be monitoring for increased risk factors to lead exposure during each well-child visit and screen children at the recommended age intervals (Ness, 2013; AAP, 2016). This was the first time the CDC included primary prevention interventions as a necessary component for tackling childhood lead exposure (CDC, ACCLPP, 2012; Ness, 2013; AAP, 2016). Screening priority also included children of immigrants, refugees, and children born outside of the US, regardless of age (CDC, ACCLP, 2012; Ness, 2013)

Blood lead screening guidelines require screening at 12-24 months of age for all Medicaid-eligible children, as well as, non-Medicaid eligible children (CDC, ACCLPP, 2012; Ness, 2013). Recommendations also included adding lead exposure to the differential diagnosis of all children with chronic, vague complaints (Ness, 2013; AAP, 2016). The Federal Drug Administration (FDA) approved a point-of-care test utilizing capillary blood in 2009. This increased the capability of primary care providers to obtain blood lead levels. Results, typically available within 3 minutes, tend to be less traumatic for children. Capillary readings of greater than or equal to 5 µ/dL required a follow-up venous sample test for confirmation of EBLL. Screening of siblings in the household of these children should also be completed, regardless of age. Screening results, whether capillary or venous, are reported to local and state agencies, as required by law. The CDC's new emphasis on primary prevention necessitates primary care providers identify and create partnerships with local lead poisoning prevention programs. State and local agencies were given jurisdiction to create screening guidelines based upon their community needs. For many communities. This led to the development of targeted screening for high-risk populations versus universal screening (Wengrovitz & Brown, 2009).

Poor health and health disparities are underlying causes of the achievement gap. Academic achievement and access to education are linked to the health of individual and populations; disparities in one contributes to disparities in the other (Fiscella & Kitzman, 2009). Despite decades of research illustrating this relationship, national policy and educational practices have not been successful in supporting integrated efforts. One identified link missing from the efforts is the lack of focus on gaps in child development on achievement (Fiscella & Kitzman, 2009). The No Child Left Behind Act (NCLB) of 2001 sought to address these gaps, with a goal of eliminating achievement gaps by 2014 (Fiscella & Kitzman, 2009). The Every Student Succeeds Act (ESSA) of 2015 replaced NCLB, in an effort to include student supports as a means to address the achievement gap, especially among traditionally underserved students (USDOE, 2019). The "Specialized Instructional Support Personnel (SISP)," as outlined in ESSA, includes school nurses and mandates each state create a plan to address student needs. ESSA also addresses the need for improved management of chronic diseases in school-age children thorough the hiring of SISPs (NASN, 2016b; US DOE, 2019).

Educationally relevant health disparities play a significant role in the achievement gap of urban, minority students (Basch, 2011). African American and Hispanic children are at significantly greater risk for higher blood lead levels. Academic outcomes of lead exposure include lower class standing in high school; increased absenteeism; lower vocabulary and grammar scores; poorer hand-eye coordination; longer reaction times; and antisocial behavior (Needleman, Schell, Bellinger, Leviton, & Allred, 1990). After controlling for other sociodemographic factors, a teenager exposed to lead, as a young child, is more likely to smoke, be truant, drop out of high school, engage in criminal activity, and become pregnant as a teenager (Denno 1993; Lane et al. 2008; Needleman et al. 1996; Nevin 2000). All of these factors contribute to both health and academic disparities. BLL surveillance in the school setting is not a standardized practice. Table 2.1 outlines BLL and the academic impacts in elementary, middle, and high school.

Table 2.1 BLL and Academic Outcomes

BLL	Elementary School	Middle School	High School
<5 µg/dL	Test scores at lower end of grade level (Miranda et al.,, 2009; Zhang et al., 2013; Magzamen et al., 2013)	Poor performance on academic test scores (Zhang et al., 2013)	Few studies done after children reach high school
$\geq$ 5 µg/dL to 9.9 ug/dL	30% more likely to fail 3rd grade 4.5 points loss in reading scores Poor social and working skills Intervention Services 7.3 µg/dL average- NOT on IEP 9.6 µg/dL average – on IEP (Evens et al., 2015; Zhang et al., 2013; McClaine et al., 2013; Magzamen et al.,2013)	Weak executive function skills, language, social and organizational skills (Canfield et al.,2003) Difficulty with reasoning, problem solving, impulsivity, emotion control (Cecil et al., 2008; Marchetti, 2003; Bellinger, 2008a)	
$\geq$ 10 µg/dL to 19.9 µg/dL	Loss of 4–8 points in full scale IQ (Lanphear et al., 2005). Scores 10.1 points lower on reading readiness tests (McClaine et al., 2013) Significantly lower 4th grade academic performance test scores (Amato et al., 2012)	Much higher probability of dropping out of school (Needleman & Gatsonis,1990). For every 10 µg/dL, IQ lowered by 4 to 7 points (Yule et al., 1981)	

All blood lead screening results conducted in Ohio are reported to the Ohio Department of Health (ODH). Children with low-level lead exposure, 0.1 to 4.9 µ/dL, are identified by ODH on an aggregate level by county. No state or local action is warranted, for these children, as they fall below the current reference value of 5 µ/dL. Children with results, 5 to 9.9 µ/dL, are identified by ODH and referred to the local health departments for monitoring. They do not receive intervention or a home visit, however, until their BLLs reach at least 10 µ/dL (ODH, 2018). Children with results greater or equal to 10 µ/dL are referred to the local health department and warrant a home inspection (ODH, 2018). There is currently no system or requirement to monitor individual children with BLL under 5 µ/dL. These children may have adverse health or educational outcomes from their low-level lead exposure, but have not received necessary referrals or monitoring to identify the impacts or interventions needed for support. There are also no communication systems in place for healthcare providers or health departments to communicate with school districts regarding children identified with EBLL. State and federal funds for lead prevention and mitigation have been fragmented and largely underfunded. Shifting the focus to address the sources of lead and supporting interventions for children to help overcome the developmental delays can improve quality of life for children and families and save billions in taxpayer dollars (Pew Charitable Trust & RWJF, 2017; Muenning, 2009).

Presentation of Theoretical Basis

The Social Determinants of Health (SDH) Framework (Appendix D) was developed on the concept of health equity, defined as "the absence of unfair and avoidable or remediable differences in health among population groups defined socially, economically, demographically or geographically" (WHO, pg.7, 2007). The SDH Framework is the interaction of context and structural determinants, which constitute the social determinants of health inequities, or the root causes of inequities in health (WHO, 2007). Context refers to the social, cultural, and political factors that influence a community's values and hierarchies. The structural determinants create a stratification of divisions with the hierarchy of the community. Examples include income, education, occupation, social class, gender, and racial/ethnicity (WHO, 2007). The interaction of the structural determinants with the intermediary determinants have in impact on the health of an individual and communities. One of the key components of this Framework is the feedback, or the impact an individual's health has on the structural determinants of health inequities, such as socioeconomic position. Ultimately, the SDH Framework provides a lens to view the complex, constant interaction of the various determinants and an individual's health status.

Bronfenbrenner's Ecological Systems Model (Appendix E) emphasizes the interactions between a child and his environments. These interactions influence how a child grows and develops. Bronfenbrenner illustrates the multiple environments in which the child interacts. The multiple environments, or systems, represent the child's immediate environment, connections, indirect environments, social and cultural values, and changes over time. Each of these environments influence each other and the child interacts with multiple environments at any single time.

The concepts of the Ecological Systems Model and the SDH are both precursors the Whole School, Whole Community, Whole Child (WSCC) framework (Appendix F). The WSCC framework, a collaborative effort between the Association for Supervision and Curriculum (ASCD) and the CDC Healthy Schools Division, grew out of the CDC's Coordinated School Health Model and ASCD's Whole Child educational initiative. The WSCC integrates tenets of education, school health, and public health into a school-specific systems model. The interconnectivity focuses on the student. The school and overall community wrap around the student to support the student's health and academic achievement. The framework is student-centered, but emphasizes the role of the overall school and community in the student's success. For a student to be safe, healthy, engaged, challenged, and supported, the school must implement evidence-based policies and practices to create a supportive school climate. These policies and practices are implemented through the 10 components of the school environment. The overall community then supports the school environment. The community represents the family, community groups and resources, businesses, other organizations, and the overall societal structure. The 10 components, comprised of 8 of the coordinated school health tenets, are rooted in the SDH. A child's environments have an impact on the child's ability to be safe, healthy, and ready to learn.

The National Association of School Nurses (NASN) released the Framework for 21st Century School Nursing Practice in 2015 (Appendix G). The framework provides a graphic representation of professional school nursing practice. Practicing school nurses strive towards the overall goal of supporting student health and academic success by contributing to a healthy and safe environment (NASN, 2016). This framework, aligned with WSCC model, emphasizes a collaborative approach to learning and health, expanding on the SDH and Bronfenbrenner's Ecological Systems Model to provide evidence-based practice guidelines for school nursing. The student, center of the focus, is surrounded by the family and school community. School nurses utilize care coordination, leadership, quality improvement, and community/public health expertise to provide best practice on a daily basis. All school nursing practice is rooted in the standards of practice for professional school nurses. The five principles of the NASN Framework guide the evidence-based care school nurses provide to help students be healthy, safe, and ready to learn.

Utility/Feasibility

The evidence supports the feasibility for the Evidence-based Practice (EBP) project in the school setting. BLL surveillance allows school nurses to focus on each individual student, as well as the impact of lead exposure on the family and overall school community. School nurse expertise in school-based surveillance and the utilization of Impact SIIS combines the community/public health and leadership components. School nurses provide care coordination through the identification, monitoring, caring, and providing referrals for students and families with lead exposure. They also serve as health experts on the school's student evaluation team, provide data, and recommendations related to the link between health and education. School nursing practice is rooted in quality improvement by assessing student and school data to inform practice changes and improve student health and academic outcomes.

Recommendations

The literature supports multidisciplinary efforts to address childhood lead exposure focusing on primary and secondary levels of prevention. Primary prevention efforts prevent children from being exposed to lead. Secondary prevention includes preventative measure the lead to early diagnosis and prompt treatment to limit disability or impairment and prevent severe health problems in the future. Blood lead screening is best practice for identifying children with lead exposure, as recommended by the CDC and American Academy of Pediatrics (AAP). The CDC "Decision Chart for Children Affected by Lead" provides guidance for identification, referral, and management of children affected by lead in the school setting (Appendix A). Impact SIIS, an effective tool for school-based immunization surveillance, can be utilized for blood lead surveillance in the school setting.

Section Three: Methods

Recommendations for Implementation of Practice Change

School-based blood lead surveillance, integrating the CDC's "Decision Chart for Children Affected by Lead," will increase the identification of at-risk students with lead exposure in the school setting. Impact SIIS will allow school nurses to identify blood lead screening results of students. This practice change will also allow school nurses and school intervention teams to better screen and refer children at risk for difficulties in academic achievement related to the adverse effects of high or chronic low-level lead exposure. A Modified Decision Chart (Appendix J) specific to Ohio school nursing practice was developed for implementation.

Plan for Implementation of EBP Practice Change

The John's Hopkins Nursing (JHN) Evidence-Based Practice Model (Appendix H) is a three-step process, known as PET: practice question, evidence, and translation. This process allowed for the identification of practice questions, collection of evidence and translation of evidence into practice to identify whether evidence-based best practices are being implemented. This model relied on a constant, interactive cycle of inquiry, practice, and learning to create practice change. This model illustrates interactions that promote a problem-solving approach to practice-based decision-making (Dang & Dearholt, 2017).

Childhood lead exposure is an environmental determinant of health. The current regulations and policies, federal, state, or local, affect the socioeconomic position of children, as well as their health outcomes because of the lead exposure. Appendix F illustrates how interventions can be put into place on the individual/family level within a household, the community level with resources and education, through improvement in public policies, and finally overall environmental interventions to help mitigate the SDH. This framework, utilized by RWJF in the County Health Rankings, is a basis for moving data into action in improving a community's health outcomes and health equity (RWJF, 2019). Conducting BLL surveillance in schools can be seen as a policy affecting the global environment. Identifying those at-risk for exposure and collecting data on screening, identification, and referral rates influences the health inequities on a global level. Utilizing the JHN EBP Practice Model allows for the determination of Impact SIIS's effectiveness in school-based BLL surveillance and the effectiveness of CDC's "Decision Chart for Children Affected by Lead" (Appendix I). The CDC's "Decision Chart for Children Affected by Lead" was modified to better-fit Ohio school nursing practice. The Modified Decision Chart allowed for the translation of the evidence into practice to determine if the intervention was evidence-based practice.

To better visualize the individual impact of lead exposure in these high-risk areas, it is essential to obtain a baseline level of current access to BLL results. Only children with BLL greater or equal to 5 μ/dL are identified individually from the ODH aggregate data. Evidence shows the importance of identifying children with low-level lead exposure, as their health and academic outcomes are impacted. This project was a practice intervention with health policy change.

Implementing the Modified Decision Chart, utilizing Impact SIIS, necessitates a minor level of change for those involved. The majority of school nurses in Ohio already use Impact SIIS for immunization surveillance on a yearly basis; increasing their readiness to implement this practice change. School district superintendents were provided with a short presentation regarding the adverse effects of lead exposure on student academic achievement prior to obtaining a district letter of support to participate in this project. An elementary school, K-3, was chosen in each district with the cooperation of the superintendent and building school nurse.

Impact SIIS is a computer-based application, requiring computer and internet access within each school setting. Each nurse required access, granted by ODH, to Impact SIIS. Confidentiality was maintained for school health records through the Federal Educational Rights Protection Act (FERPA). The medical records obtained from Impact SIIS were protected under state regulations. Building school nurses performed the data collection and only shared student-de-identified data. The Ohio State University Institutional review Board (IRB) deemed the project Quality Improvement (QI) and did not need further approval. This project was also submitted to the ODH IRB to ensure the protection of human subjects, as students are an at-risk population. The project deemed not reviewable, was an evidence-based practice project not meeting the definition of research.

Implementation of this project was part of the larger work of the Richland–Ashland Counties Lead Prevention Collaborative. Recent events, including the Flint Water crisis, created an opportunity for increased awareness of lead exposure in the community. Increased awareness may help facilitate support for the implementation and dissemination of the project and results. Schools are currently under great scrutiny in relation to test scores and student performance. This project provided an opportunity for districts to better identify ways to support their students and meet a timely need. Healthy People 2020, recommends utilization of primary prevention intervention efforts to accelerate progress toward the goal of reducing EBLL in children (CDC, 2004), including low-level lead exposure (CDC, ACCLPP, 2012). Coordinated efforts with the Richland-Ashland Counties Lead Prevention Collaborative provide ongoing support for the school districts and communities to support efforts of lead prevention and risk reduction.

The project design was an evidence-based practice implementation with a pre- and post-retrospective records review to inform practice policy. Quantitative methods and chart review were utilized to collect student blood lead screening results. Qualitative methods were utilized to survey the school nurses regarding their experience with the Modified Decision Chart and the use of Impact SIIS for school-based BLL surveillance. The Modified Decision Chart (Appendix I) guided schools nurses in elementary schools, in high-risk geographical areas, through the identification and referral of children in grades Kindergarten through Grade 3. The CDC Decision Chart, created by educators, outlined the overall process of addressing the needs of children with lead exposure in the school setting. The Modified Decision Chart provided guidance specific to school nursing practice in Ohio. The following steps, outlined below, create a standardized approach and process across multiple implementation sites.

1. Trained school nurses in each of 2 elementary schools (K-3), including the modified decision chart, Impact SIIS, and data collection paperwork.
2. School nurses provided parents with notifications of BLL surveillance in student take home folders. Similar explanatory documents were posted on the school website for parent access. One week was allotted for parents if they wanted their child excluded. All students with parental notice of exclusion were excluded from the following steps. They were counted in the aggregate total for students opting out and in the total number of students per grade only.
3. School nurses reviewed each student school health record for BLL results for students K-3. School nurses documented BLL identified via nursing note in school health record.
4. School nurses documented BLL data and data source for individual students on Data Collection Form 1.
5. School nurses aggregated the individual student data from Data Collection Form 1, by grade, on Data Collection Form 2.
6. School nurses reviewed Impact SIIS for all students K-3 for recorded BLL.
7. School nurses recorded BLL on student school health record.
8. School nurses documented BLL data from Impact SIIS in for individual students on Data Collection Form 3.
9. School nurses completed parent results letter for each student K-3. These letters were sent to parents in student folders in sealed envelopes. Parents received an email notification that the letters were coming home. (These letters may have also been mailed based on the process used by the school).

10. School nurses compiled referral lists according to the Modified Decision Chart for Ohio School Nurses.
    - All students without recorded BLL results (from baseline or intervention chart review) were referred for screening.
    - All students with BLL < 5 µ/dL were referred for monitoring.
    - All students with BLL > 5 µ/dL were referred to Child Find and the local health department.
    - School nurse will verify student results > 5 µ/dL as known cases with the local health department.
11. School nurses documented referral data and data source on Data Collection Form 3.
12. School nurses provided building principal with list of students referred for Monitoring and Child Find.
13. School nurses compiled the individual data from Data Collection Form 3 into aggregate numbers by grade on Data Collection Form 4.
14. School nurses shared Data Collection Form 4 with PI (Stanislo) via email.
15. School nurses completed Post-Implementation Survey via Google Survey.

The time expected to complete the individual student baseline and implementation record review by the school nurses was 1-3 weeks. The school nurse for each participating elementary school collected the BLL results for their students. This timeline was generous to allow for interruptions in the school nurse's daily practice. Data aggregation data took an additional 1-2 weeks for the school nurses to compile. The investigators did not participate in the data collection process, as the school nurses provided feedback on the overall process of BLL surveillance and the use of the Modified Decision Chart. The investigators were available by phone, email, and in-person to answer process questions. The school nurses provided aggregate results to the Primary Investigator (PI) when the data was completed and documented on the aggregate data collection forms. The aggregate data was analyzed over 2-4 weeks, including review of the

ODH data for comparison of updated county screening rates. The total time commitment for the study was approximately 12 weeks.

Evaluation.

***Outcome evaluation*.** The outcomes were measured pre- and post- implementation of the Modified Decision Chart for Ohio School Nurses, utilizing Impact SIIS by the district school nurses. The aggregate data was analyzed by BLL, school, grade, source of BLL result, screening performed per recommended age interval, and type of referral. Measurements included the following data points:

- Percent of students with a history of receiving blood lead screening;
- Percent of students needing referrals for screening;
- Percent of student referrals for monitoring, for blood levels below 5 μ/dL;
- Percent of student referrals to Child Find and Health Department (HD) for EBLL over 5 μ/dL;
- Percent of students with blood lead levels above 10, 15, 20, 25 μ/dl;
- Percent of BLL results obtained from Impact SIIS vs other methods;
- Percent of students receiving BLL screening per recommendations.

School nurses identified students with recorded BLL, without recorded BLL, and quantified the lead levels of the students with recorded BLL. The surveillance process was completed using a project-specific data log. The aggregate data log supplied to the PI by the school nurses reported only de-identified aggregate data. The data logs can be found in Appendix J. The following questions for future practice were considered following the outcome evaluation:

(1) How effective is Impact SIIS as a surveillance tool for blood lead levels?

(2) How does the screening data of each school compare to ODH prevalence data for the identified population?

(3) What benefit does this data provide to school districts to support academic achievement?

Insights into the Modified Decision Chart and Impact SIIS were obtained through quantitative and qualitative survey of the participating school nurses focusing on feedback on the overall experience, time, process implementation, data documents, Modified Decision Chart, benefits, and difficulties.

Section Four: Findings

Results/Outcomes

The purpose of this project was to improve the identification and management of children exposed to lead through the implementation of school-based blood lead surveillance. BLLs are required to be entered in to Impact SIIS at the time of screening. BLL results are entered in to Impact SIIS by laboratory personnel when a venous sample is collected and analyzed or by the provider’s office using point-of-care testing results. BLLs are not routinely monitored in K-12 school health records; however, screening results can be shared with the school or can be found by the school nurse in Impact SIIS during the immunization surveillance process.

School nurses in the intervention schools completed a baseline audit of school health records to determine if BLL were routinely included as part of school health physicals, immunization reports previously printed from Impact SIIS, or communicated with the school by other means. Results of the baseline audit indicated blood lead screening results were not routinely available in school health records. The nurse from School A, failed to find any BLL screening results in the student health for students in grades Kindergarten to 3. The nurse from School B found 10 of 419 student health records contained blood lead screening results for students in grades Kindergarten to 3, representing 2.4% of all students. Of these 10 students, all 10 had identified BLL screening results between 1-4.9 µg/dL and the records were provided to the school via paperwork from the PCP or HD. One student from School A and School B were excluded from the review per parent request.

The intervention audit required the school nurses to search Impact SIIS for recorded blood lead screening results for each of the students in grades Kindergarten to 3. For School A, 482 of 482 (100%) student blood lead screening results were identified in Impact SIIS. For School B, 248 of 419 (59%) student blood lead screening results were identified in Impact SIIS. Screening results identified from

Impact SIIS were subsequently recorded in the school health records for each student. Of all students with recorded BLL screening results, 100% from both School A and B, had received screening according to CDC guidelines. Figure 4.1 displays the overall impact of the intervention.

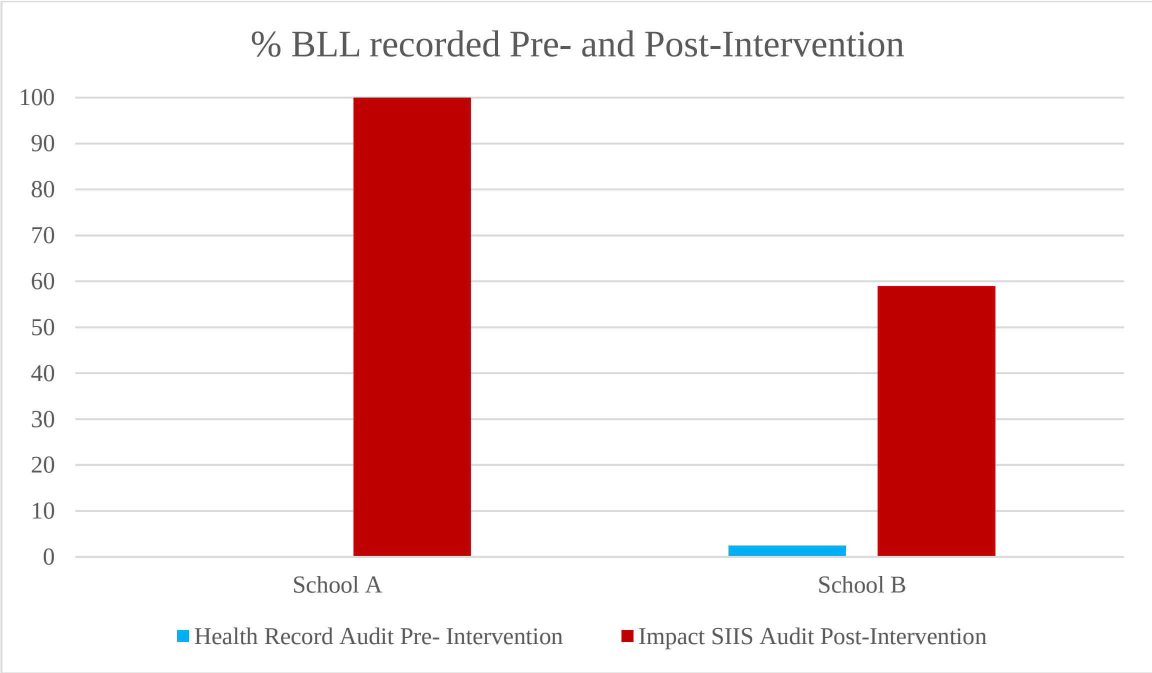

Figure 4.1 BLL Screening Rates

Intervention audit data were categorized by student grade, BLL range, and type of referral per the Modified Decision Chart. School A data indicated 211 students (44%) with BLL screening results below 1.0 µg/dL; 262 (54%) between 1 and 4.9 µg/dL; and 9 students (2%) between 5 and 9.9 µg/dL. There were no students at School A with BLL screening results above 9.9 µg/dL. School B data indicated 0 students (0%) with BLL screening results below 1.0 µg/dL. Of the 248 students with recorded BLLs, 219 (88.3%) had BLL screening results between 1 and 4.9 µg/dL; 20 students (8.1%) between 5 and 9.9 µg/dL; 4 students (1.6%) between 10 and 14.9 µg/dL; 4 students (1.6%) between 15 and 24.9 µg/dL; and 1 student (0.4%) greater than 25 µg/dL. Figures 4.2 and 4.3 illustrate the BLL rates by school and grade.

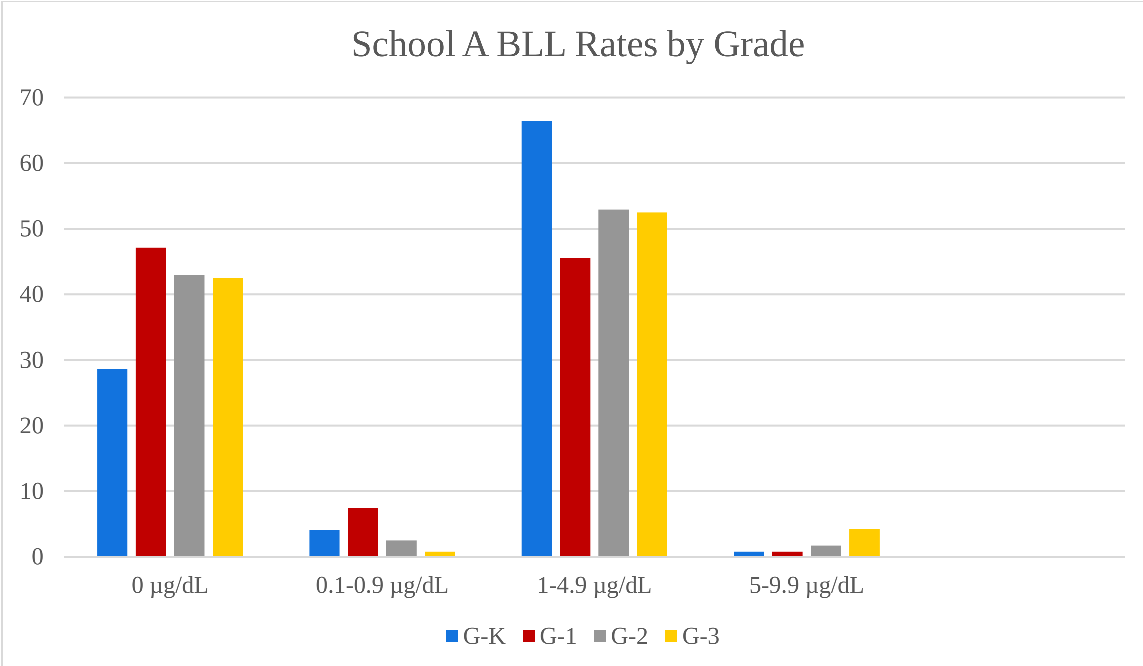

Figure 4.2 School A: BLL Rates by Grade

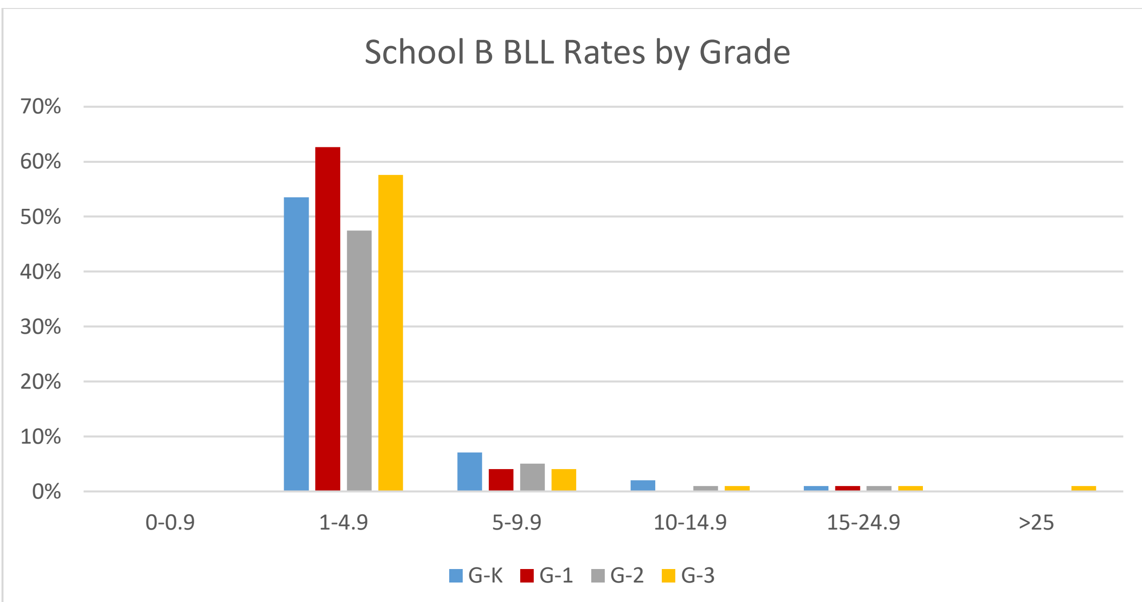

Figure 4.3 School B: BLL Rates by Grade

Although the majority of students for School A have BLL below 5 µg/dL, Kindergarten children had the highest prevalence of BLL between 1-4.9 µg/dL. Grade 3 children had the highest prevalence for BLL between 5-9.9 µg/dL. The majority of students at School B also had BLL below 5 µg/dL; students in Grade 3 also had the highest prevalence of BLL overall, including a student with BLL greater than 25 µg/dL. Students in Kindergarten had the highest prevalence of BLL at 5-9.9 µg/dL and 10-14.9 µg/dL.

The Modified Decision Chart provided guidelines for referral of students for screening, monitoring, and the referral to the health department (HD), and/or Child Find based upon their BLL. School A data indicated 280 (58%) of all students were referred for monitoring and 9 (1.8%) were referred to the HD and Child Find. No action was required for the 194 students (40.2%) with BLL of 0 µg/dL. School B data indicated 219 (52.6%) of all students with a recorded BLL were referred for monitoring and 29 (3.2%) were referred to the HD and Child Find, respectively. There were 171 (41%) students with no BLL results available; they were referred for BLL screening. The results of these screenings are pending. Figure 4.4 and Table 4.1 illustrate the referral rates by school for each type of referral.

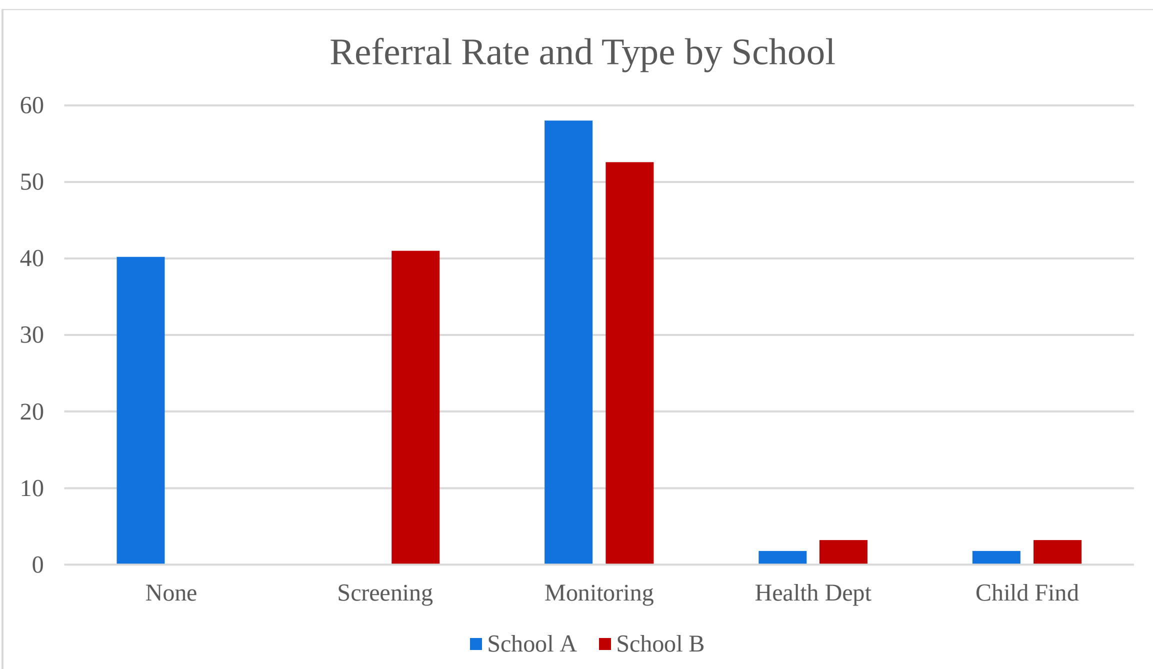

Figure 4.4 Referral Rates by Type and School

Table 4.1 BLL and Referral Rates by School

	School A	School B
% students receiving BLL screening	100%	59%
% students needing referral for BLL screening	0%	41%
% students referred for monitoring	58%	52.6%
% students referred to HD	2%	3.2%
% students referred to Child Find	0%	3.2%
% BLL recorded in Impact SIIS	100%	100%
% students receiving BLL screening 1-6yrs	100%	100%
% students 0 μg/dL	40%	0%
% students 0.01-0.9 μg/dL	4%	0%
% students 1-4.9 μg/dL	54%	88.7%
% students 5-9.9 μg/dL	2%	8.1%
% students 10-14.9 μg/dL	0%	1.6%
% students 15-24.9 μg/dL	0%	1.2%
% students $\geq$25 μg/dL	0%	0.4%

The school nurses participated in a post-implementation survey at the completion of the project to query their experience in using the Modified Decision Chart, both in relation to workload and effectiveness of the process and components. The survey questions are outlined in Table 4.2 and the results are outlined in Figure 4.5. A Likert scale was utilized with 1 representing low and 5 representing high.

Table 4.2 Post-Intervention School Nurse Survey

Survey Question	Survey Responses
On a scale from 1 to 5, how cumbersome was the BLL surveillance process? **1 not cumbersome, 5 very cumbersome**	2 3
On a scale of 1 to 5, how time intensive was the BLL surveillance process? **1 not time intensive, 5 very time intensive**	2 4
On a scale of 1 to 5, how efficient was the Modified Decision Chart in guiding your referral decisions? **1 not efficient, 5 very efficient**	4 5
What was the most difficult part of the BLL surveillance?	So far, the most difficult part has been the phone calls of parents "freaking" out about the lead level letters. Many

Survey Question	Survey Responses
	parents knew that their children had been tested but since they only get results if the number is greater than 5, many parents were concerned that their child had a lead level greater than 0. Having uninterrupted time to complete the surveillance. Also, having a private work space available for auditing the physical files.
What was the most difficult part of using the Modified Decision Chart?	Understanding it! Ha ha. Once I knew what I was doing it was not bad. I did not find any part of it difficult.
If you were to perform BLL surveillance again, what would you do differently?	I would make sure I understood the forms better. I would plan for more time to complete the surveillance. I would print out the ppt instructions for easier access to help me stay on task.
If you were to use the Modified Decision Chart again, what would you do differently?	not sure I did not actually use it very much. I depended on the ppt instructions more but I can see where if this became an annual surveillance it would be helpful to have the decision chart as a tool.
On a scale of 1 to 5, how much do you know about the health and academic impacts of childhood lead exposure? **1 very little knowledge, 5 very knowledgeable**	3 3
On a scale of 1 to 5, how much do you know about your community's resources for lead prevention and management? **1 very little knowledge, 5 very knowledgeable**	3 3
On a scale of 1 to 5, how valuable to you think the BLL surveillance results will be to your students? **1 not valuable, 5 very valuable**	5 5
How do you think your experience would have differed if completed in August vs. January?	I think that it would have flown nicely with looking up immunization records I think it would have been less cumbersome doing it in August because I was already looking up students in Impact SIIS for immunizations. The other thing that made it more cumbersome is that I looked up EVERY student in the building. I am guessing in subsequent years if this became routine we would treat it like immunizations and do Kdg and new students.

Survey Question	Survey Responses
Is there any additional feedback you would like to share?	I think that this was a great eye opener for the staff in the building. I think it put some missing pieces together. Thanks for allowing me to participate with this project. I am interested to see how compiling this information will affect the students at my school.

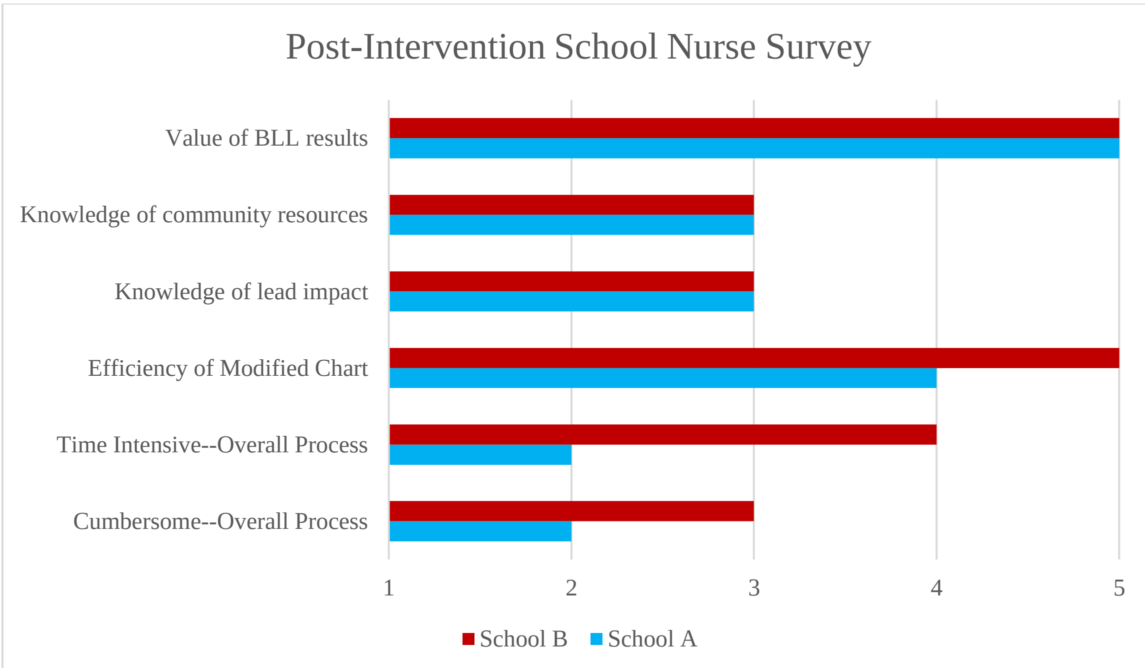

Figure 4.5 Post-Intervention School Nurse Survey

The nurses also provided qualitative feedback. Specifically, they reported that BLL surveillance would be easier to implement at the beginning if the school year in August when they also review immunization records. In addition, they identified barriers to effective completion of the surveillance including interruptions during the day, limited workspace, and explaining low-level exposure to parents. Benefits of BLL surveillance included the overall benefit for student health and well-being and perception by the school principals that the referral process provided school staff with valuable information to better identify students with academic needs.

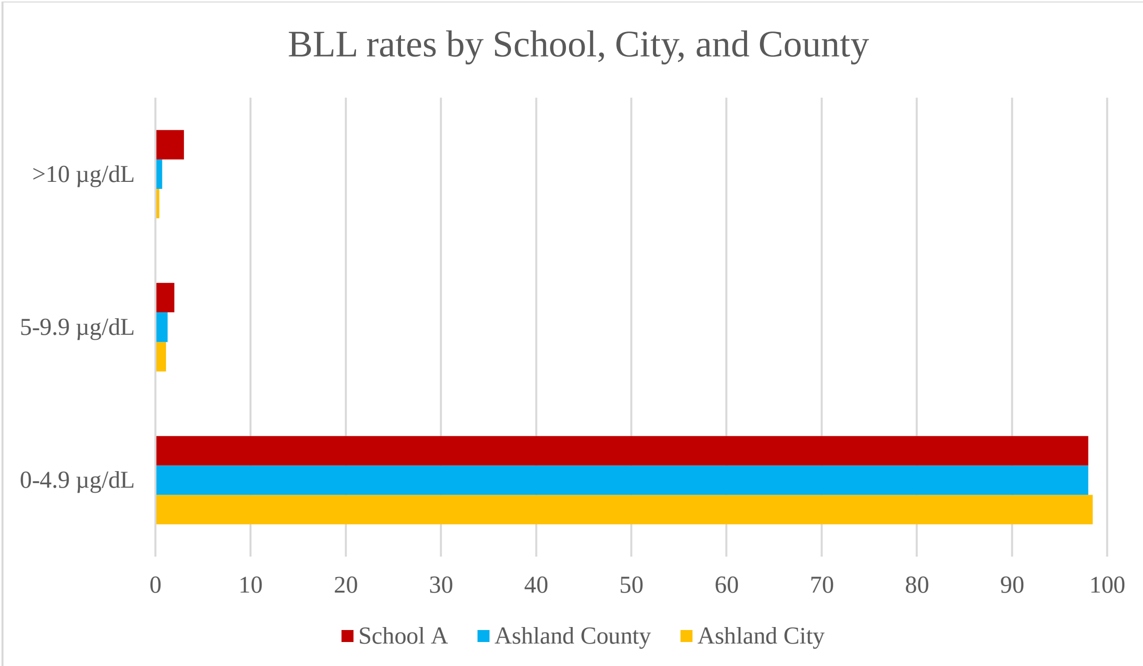

Figure 4.6 BLL: School A, City, and County

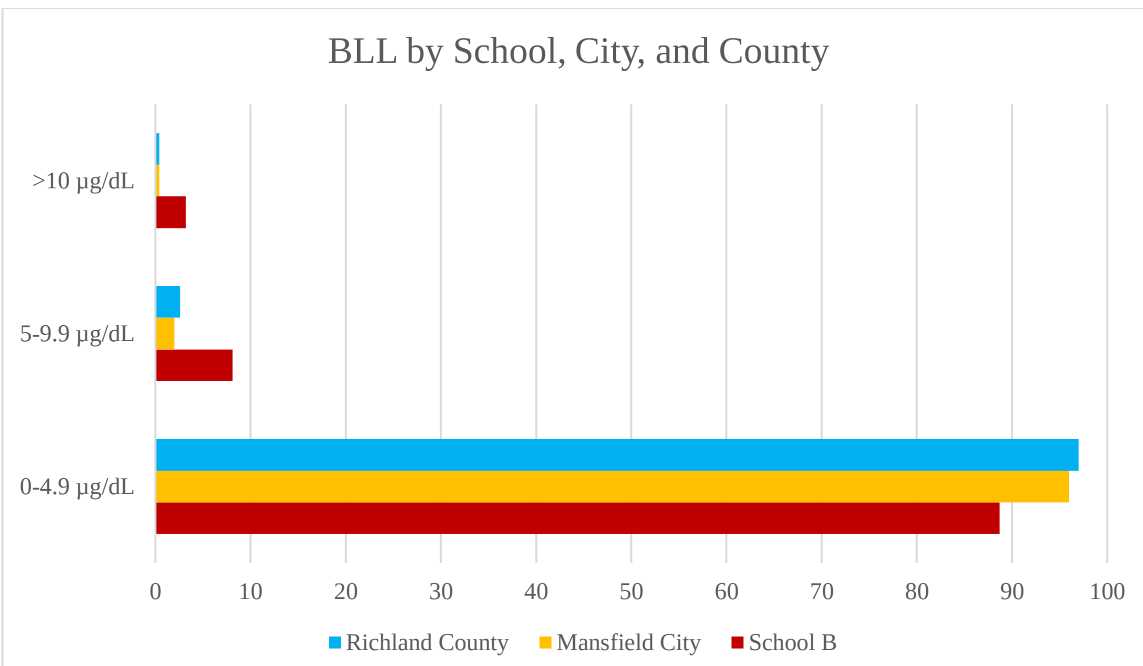

Figure 4.7 BLL: School B, City, and County

Discussion

Effectiveness of Impact SIIS as a surveillance tool for blood lead levels. The purpose of this project was to implement the Modified Decision Chart in the school setting and utilize Impact SIIS to improve the surveillance of childhood BLL screening in high-risk geographical areas, such as Ashland and Mansfield. The screening rate for School A was 100% and 100% of the students received BLL screening according to CDC and Ohio guidelines. The screening rate for School B was 59%, but 100% of these students were screened according to the CDC and Ohio guidelines. The screening rate for School B was consistent with the estimated screening rate of 2/3 (66%) nationally, as identified by Raymond et al. The population at School B represented a higher percentage of non-Hispanic black students, 9.4% vs 0.8% for School A. This represents a difference in risk factors for School B vs. School A, as indicated by White et al and supported by the SDH (White et al, 2016). Additional risk factors for School B, as illustrated in Table 2.1 included increased overall poverty rate, high percentage of family mobility, and lower mean household income.

The disparities seen in the County Health Reports further illustrates the increased risk for students at School B for lead exposure. The PCP ratio represents a discrepancy in access to primary healthcare providers. It would be beneficial to note whether the difference in screening rates is due to a true reduction in screening or reduction in reporting BLL screening results through Impact SIIS. This may be more common from point-of-care capillary testing versus lab-based venous testing. The data indicated Impact SIIS is an effective method to perform school-based BLL surveillance. Further school-based BLL surveillance by school nurses, coupled with BLL screening at school-based healthcare centers (SBHC) may provide an ideal collaboration to provide targeted screening, referral, and follow-up in at-risk communities.

Comparison of School A and B screening data to ODH prevalence data. BLL rates varied between School A and B for BLL ranges 0-4.9 μg/dL, but were similar in overall percentage under 5 μg/dL. Data from School A indicated 44% of all students had BLL less than 1 μg/dL, with the majority of those students (91%) having BLL of 0 μg/dL. Students with BLL between 1-4.9 μg/dL represented 54%

of students in School A. ODH data (2017) indicated 98-98.5% of all children screened for BLL in 2017, within in city and county limits, had BLL less than 5 µg/dL. School A and ODH (2017) both indicated approximately 98% of children in this high-risk geographical area had BLL less than 5 µg/dL. For School A, 54% of all students had BLL between 1 and 5 µg/dL. School B had 0 (0%) students with BLL less than 1 µg/dL and 88.7% of all students with BLL between 1-4.9 µg/dL. ODH data (2017) indicated 96-97% of all children screened for BLL in 2017, within in city and county limits, had BLL less than 5 µg/dL. School B results indicated approximately 10% difference from ODH (2017) data of children with low-level exposure. This discrepancy in data may indicate an improvement in preventative programs over the 5-8 years, since the students were screened. From an educational perspective, it is important to identify the number of students with low-level lead exposure represented by BLL less than 5 µg/dL.

Overall BLL rates for students over 5 µg/dL varied from school to school, but also from ODH (2017) data for city and county and the ODH (2016; 2016b) predicated prevalence. School A data indicated 2% of all students had BLL between 5-9.9 µg/dL and 0% of students had BLL greater than 10 µg/dL. This is almost double the ODH (2017) city and county data of 1.1-1.3% of all children screened. The ODH (2017) data indicated 0.4-0.7% of children screened had BLL greater than 10 µg/dL. The ODH (2014) data predicted 11.5-18.2% of all children had BLL greater than 5 µg/dL. School B data indicated 8.1% of all students had BLL between 5-9.9 µg/dL , 1.6 % between 10-14.9 µg/dL, 1.2% between 15-24.9 µg/dL, and 0.4% greater than 25 µg/dL for a total of 11.3% of students with BLL over 5 µg/dL. ODH (2017) data indicated 2-2.6% of all children screened had BLL between 5-9.9 µg/dL and 0.4% greater than 10 µg/dL. ODH (2016a; 2106b) data indicated a predicated prevalence of 18.3-27.3% of children with BLL greater than 5 µg/dL. School B data is significantly higher than the ODH (2017) data, but 7-16% less than ODH (2016a; 2106b) data. These results are illustrated in Figures 4.6 and 4.7. See Appendix L for exact values. This indicated the children attending School B were experiencing higher rates and quantities of lead exposure than School A. The number of students (41%) at School B with no BLL results available may amplify this difference once the screening results are obtained. Differences in housing, access to health care and transportation, poverty level, ethnicity, and access to lead prevention resources and programming may account for the increased rates and exposure to lead for students in School B. This further supports the significance of the SDH and the work of White et al (2016).

Benefit of screening and referral data to school districts. The Modified Decision Chart guided school nurses through the identification and referral of students with lead exposure in the school setting. Students were referred based on their identified BLL screening results. Students with no BLL results available were referred for blood lead screening. Students with BLL greater or equal to1 and less than 5 µg/dL were referred for monitoring. Monitoring included periodic surveillance of the student's health, behavior, and academic histories to identify changes indicating the need for further assessment in the school setting. Students with BLL greater than 5 µg/dL were referred to Child Find and the local HD. Child Find is a legal requirement of schools to find and evaluate all children with a known or suspected disability, as they may qualify for intervention services. Each district has processes in place for the identification, evaluation, and management of these students. This project does not examine the Child Find results, only the BLL results and subsequent referrals. Although HDs do not intervene until the BLL is greater than or equal to 10 µg/dL, students with BLL less than 5 µg/dL were still referred to the HD, per the Modified Decision Chart, to ensure children did not slip through the cracks. This is common with increased mobility of families.

The benefit to school districts from BLL surveillance is reliant on the ability to identify students with lead exposure. This identification included quantifying the BLL of students with a history of screening and identifying students in need of screening. Once identified, students were referred appropriately, per the Modified Decision Chart. The Modified Decision Chart effective guided the identification and referral of students with lead exposure it the school setting. Providing schools with an evidence-based practice to better identify and manage students at risk for adverse health and academic outcome is essential in addressing the needs of the whole child.

A review of the Post-Implementation indicated several patterns. The time needed to complete the process was fair to moderately high. This was likely impacted by project implementation in January, rather than August. The utilization of the project data collection forms and overall surveillance process were described as moderately low to neutral in terms of difficulty. The Modified Decision Chart was identified as moderately to highly efficient in guiding school nursing practice. School nurse knowledge of health and academic impacts of childhood lead exposure and community resources were indicated as neutral. Qualitative feedback was very positive regarding completing this surveillance process in August instead of January. The perceived benefits of collecting BLL data for the school, teachers, and students. The largest barriers to completing this BLL surveillance were finding uninterrupted time and private workspace. It was also noted that dealing with parents concerned about low-level lead exposure was time consuming. The process could be improved for the next time by updating the data collection sheets to include a 0 µg/dL data collection point, as well as a no records available for the school and grade level data. It was recommended to implement BLL surveillance in August to coincide with the annual immunization surveillance process.

Limitations

The timing of implementation was a limitation of this project. Ideally, BLL is best implemented at the beginning of the school year when immunization surveillance and student health records reviews are completed. Immunization surveillance occurs from August to October each school year and routinely utilizes Impact SIIS. Combining these processes would allow for maximum efficiency in time and effort. The data collection was delayed until January and February for this project due to an extended period required for IRB approval. Snow and weather cancellation days and increased student illness visits during flu season led to increased time needed for data collection by the school nurses.

The health services model of each district affected the data collection process and implementation of the Modified Decision Chart. School A was staffed with a full-time clinic aide and a district RN who supervised and rotated between buildings. This model of school health services allowed for a team approach to triage student clinic visits and auditing student health records and Impact SIIS. School B is staffed with a fulltime school nurse. A substitute nurse was provided by the district to help cover the student clinic visits while the school nurse audited the student health records. School C was staffed by school secretaries and a part-time district nurse. The part-time nurse covered student health needs and medication administration. School C did not receive allotted nurse time on a daily or weekly basis, unless called for an emergency. Completing the baseline student health record audit and implementation of the Impact SIIS intervention was impractical during the middle of the school year. For this reason, School C was excluded as a project site.

The recording of BLL in Impact SIIS was also a limitation. There was no way to ensure all blood lead screening results were entered into Impact SIIS. Additionally, lab ranges for BLL screening results differ from health system to health system. Some labs may report the lowest BLL reading <2 µg/dL, while others may indicated specific low-level results. It would be of note to identify the sensitivity of lab testing versus point-of-care testing, as both venous and capillary results were reported in Impact SIIS. For the purposes of this project, a venous sample was not required; capillary or venous BLL screening result was accepted as evidence of screening. Prior to treatment or further medical intervention, a venous sample would be mandated by the HD.

Section Five: Recommendations and Implications for Practice

Implications for Practice

Prevention of childhood lead exposure is key, but it is also critical to identify children already exposed to lead to ensure they receive the appropriate academic, behavioral, and health interventions and services (Pew Charitable Trust & RWJF, 2017; Muenning, 2009). The first step in identifying these children is improving the BLL screening for at-risk children. Removing the barriers to BLL screening and reporting screening results in Impact SIIS needs to involve a multidisciplinary team of parents, healthcare providers, State Medicaid and Children's Health Insurance Program (S-CHIP), and school nurses. The addition of school nurses to this multidisciplinary team is supported by this project. School nurses have ready access to state and local data for BLL screening results and have the expertise to identify at-risk children with lead exposure. It is the recommendation of the PI to perform BLL surveillance for all Ohio students in grades Kindergarten to 3. The initial surveillance would include all students; subsequent year surveillance would only necessitate students in Kindergarten and new to the school in Grades 1 to 3. This surveillance process mimics the current immunization surveillance process in Ohio schools. School-based

BLL surveillance, utilization of the Modified Decision Chart and Impact SIIS, is evidence-based practice. Medicaid and S-CHIP funding for school districts participating in the identification and referral students per the Modified Decision Chart. Advocating for the identification and referral of children with a history of BLL screening results of 5 µg/dL or greater to Child Find would allow schools to receive Medicaid funding for the educational evaluation and services of Medicaid-eligible children with lead exposure. Revising the criteria for qualification for Early Intervention services to include lead exposure at or above the current CDC reference value would also provide much needed supports for children ages 0-3 years. These children would benefit from early intervention supports to maximize neurologic development prior to entering preschool or Kindergarten. It is also important that BLL screening results to be shared between preschool and K-3 student health files. In at-risk geographic areas, these records should include BLL screening results from Medicaid EPSDT exams. A future extension of this project includes implementation of school-based BLL surveillance in the public preschool setting. Comparison of the availability of BLL screening results in preschool health records versus K-3 health records is warranted. This would also increase the opportunity for the identification and referral of students at an earlier age to increase the benefits of intervention services during a critical period of neurological development. This project highlights the effectiveness of the school-based BLL surveillance, utilizing Impact SIIS and the Modified Decision Chart, on the identification of at-risk children with and without blood lead screening results, health and educational referrals, and monitoring of students with a history of lead exposure.

The next steps include working through the remainder of the Modified Decision Chart to monitor, evaluate, and manage the students with identified BLLs. The PI will provide collaborative support to school and district administrations in mapping the most appropriate steps and resources needed to support the academic and health needs of the students. Recommendations also include implementation of school-based BLL surveillance in the districts' remaining elementary schools this August. The participating school nurse from each district can now serve as a resource in the remaining schools. The PI will continue to work with the Ashland-Richland Counties Blood Lead Prevention Collaborative to identify and provide resources to the schools and communities-at-large. Dissemination of project results is imperative in addressing the complex issue of childhood lead exposure. Additional at-risk areas in Ohio will be identified for implementation of school-based BLL surveillance. Dissemination of these results will provide evidence for the need of additional school districts to address childhood lead exposure within their schools and communities.

Public policy recommendations supported by this project include: “improving blood lead testing among children at high-risk of exposure, ensuring access to developmental and neuropsychological assessments and appropriate high-quality programs for lead-exposed children, improve public access to local data, fill gaps in research to better target state and local prevention and response efforts” (Pew Charitable Trust & RWJF, pp2, 2017). The Health Impact Project, formed in 2017, is a collaborative effort between the Pew Charitable Trusts and the Robert Wood Johnson Foundation (RWJF). Practice implications identified through this project’s report, *Ten Policies to Prevent and Respond to Childhood Lead Exposure*. Two of the five polices included: “providing the roughly 1.8 million children with a history of lead exposure with targeted, evidence-based interventions could increase their lifetime family incomes by more than $100,000…and eradicating lead paint hazards from homes of children in low-income families would protect more than 311,000 children and provide $3.5 billion in future benefits” (Pew Charitable Trust & RWJF, pp 2, 2017). The report estimated a total savings of $18.5 billion in federal funds and $9.6 billion in state funds from implementation of the efforts focusing on addressing sources of lead affecting children and interventions to support children overcoming the developmental delays associated with lead exposure (Pew Charitable Trust & RWJF, 2017; Muenning, 2009). These savings were associated with higher lifetime earnings and savings in the healthcare, educational, and criminal justice systems.

Healthy People (HP) represents U.S. public health policy objectives by decade. HP 2020 addresses lead exposure and screening in children under the environmental health objectives. HP 2020 objectives are reducing of BLL in children ages 1-5 years and reducing the mean BLL in children (ODPHP, 2019) The 97.5 percentile BLL from 2005-2008 was 5.8 µg/dL. The HP 2020 goal was to reduce by 10% to 5.2 µg/dL. Preliminary estimates indicate the current 97.5 percentile is 4.3 µg/dL, representing a significant improvement and need to consider lowering the CDC reference vale under 5 µg/dL (ODPHP, 2019). The baseline mean of 1.8 µg/dL, set in 2003-2004, with a goal of 10% reduction to 1.6 µg/dL. This goal was new to the HP 2020 objectives, as it was not addressed in previous HP initiatives (ODHPH, 2019). Preliminary estimates indicate the current mean is 1 µg/dL. These gains in the reduction of lead exposure in children provide momentum and an ideal opportunity for continued advocacy efforts. As we approach the year, 2020, this project indicates lead exposure continues to be a public health crisis needing attention and funding.

On the local level, the Children's Defense Fund of Ohio outlines three steps for responding to the lead crisis in Ohio.

- Deepen investments in lead abatement efforts, especially high-risk dwellings.
- Ensure all children who are at-risk of lead poisoning are tested each year, especially those in identified high-risk communities.
- Increase investments in early intervention services to provide kids who have tested positive for lead poisoning with additional support for healthy physical, mental, and social emotional development that better prepares them for kindergarten (Children's Defense Fund of Ohio, 2019).

National and state public policy emphasize the need to increase identification and screening of at-risk children. Multidisciplinary efforts need to target prevention and mitigation of lead exposure. In addition, efforts must continue to identify children already exposed to lead, provide access to health and educational services, and address barriers to screening. School-based blood lead surveillance in Ohio schools is a critical step in addressing the local needs of Ohio's communities and children.

Conclusion

Addressing the public health issue of childhood lead exposure requires both a macro and micro perspective. Public policy, funding, and environmental exposures require a larger, overall perspective. Identifying barriers, resources, and analyzing local data require a combination of the macro and micro perspectives. Identifying and managing the individual children and families impacted by the adverse effects of lead require a micro perspective. Learning to address and manage the whole child takes all of these perspectives into account. A child is a product of the environment, community, and experiences he/she encounters. Combatting this crisis requires collaborative efforts to identify and link the overlapping, interconnected components of public health. The identification of schools as communities and school nurses as experts in public health is essential to improving the health and academic outcomes of millions of children. Identifying children exposed to lead, even at low levels, provides them the best opportunity for lifelong success. Linking children to evidence-based, high-quality intervention services have shown to reduce skill and behavioral deficits (Pew Charitable Trust & RWJF, 2017). It's been said it takes a village to raise a child. In the case of preventing and managing childhood lead exposure, it truly takes a community approach and the time to act is now.

Identify Methods for Dissemination

A formal presentation is scheduled with each school districts' administration prior to the end of this school year. A community presentation, including teachers and families, will also be scheduled by each district. The goal is to present prior to the beginning of the next school year. The PI, in collaboration with the Ashland-Richland Counties Lead Prevention Collaborative will provide ongoing support to the school districts. Each district will identify next steps, according to the Modified Decision Chart, to move forward with the monitoring and evaluation of students on the referral lists. The school nurses will share data and experiences with fellow nurses in each district to identify next steps for BLL surveillance within the district. The project and results will be shared as a scholarly poster and/or presentation at upcoming professional conferences and a manuscript will be submitted for peer-review publication to *The Journal of Pediatric Healthcare*.

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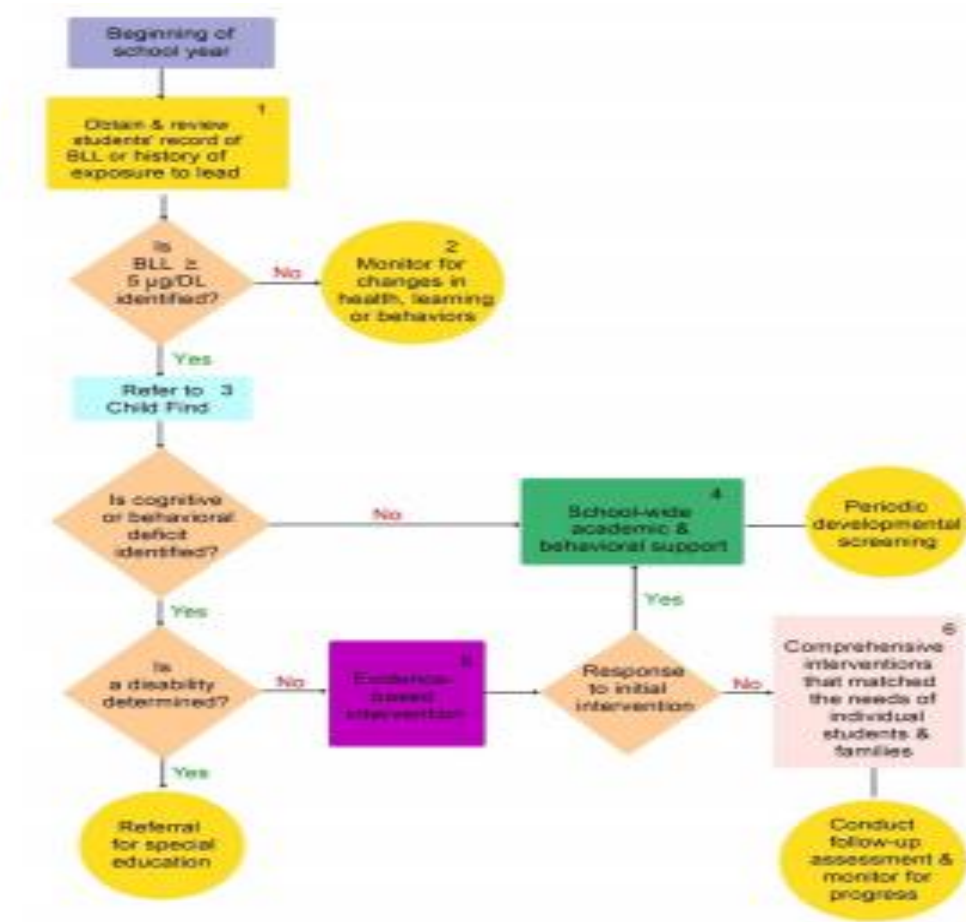
Appendix A



CDC “Decision Chart for Students Affected by Lead” (CDC, 2015).

Appendix B

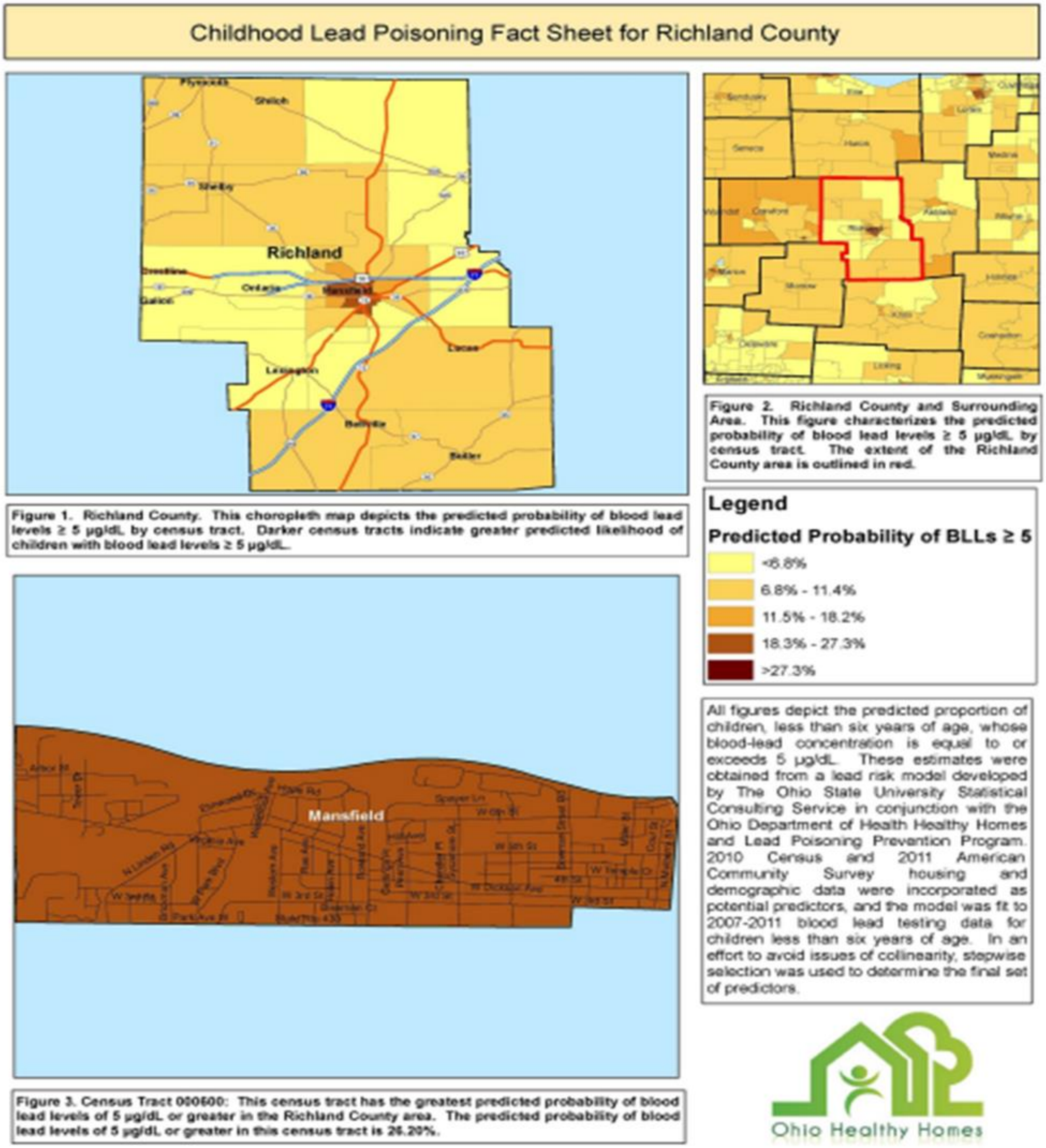

Childhood Lead Poisoning Fact Sheet for Richland County

Figure 1. Richland County. This choropleth map depicts the predicted probability of blood lead levels ≥ 5 µg/dL by census tract. Darker census tracts indicate greater predicted likelihood of children with blood lead levels ≥ 5 µg/dL.

Figure 2. Richland County and Surrounding Area. This figure characterizes the predicted probability of blood lead levels ≥ 5 µg/dL by census tract. The extent of the Richland County area is outlined in red.

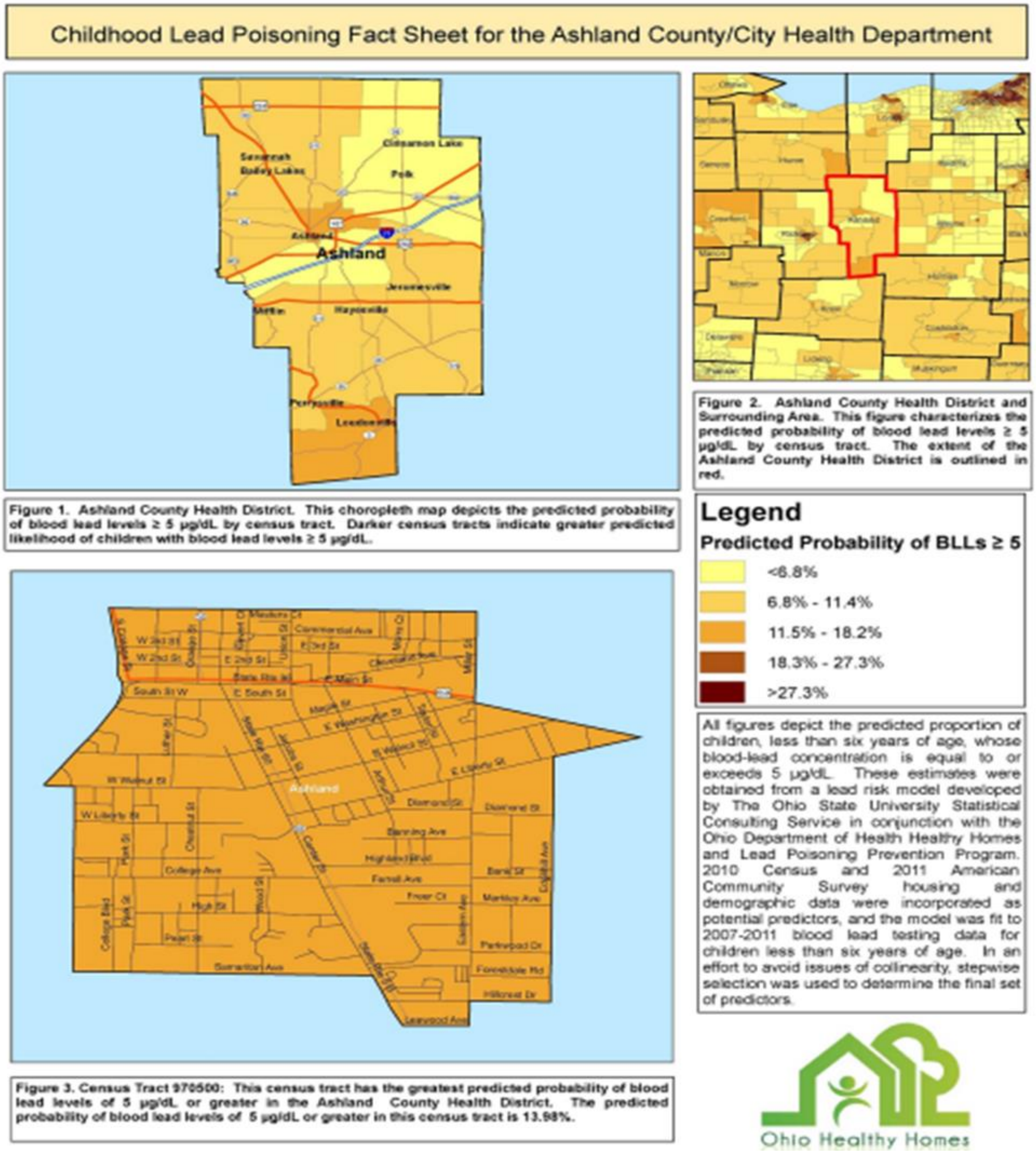
Figure 3. Census Tract 000600: This census tract has the greatest predicted probability of blood lead levels of 5 µg/dL or greater in the Richland County area. The predicted probability of blood lead levels of 5 µg/dL or greater in this census tract is 26.20%.

All figures depict the predicted proportion of children, less than six years of age, whose blood-lead concentration is equal to or exceeds 5 µg/dL. These estimates were obtained from a lead risk model developed by The Ohio State University Statistical Consulting Service in conjunction with the Ohio Department of Health Healthy Homes and Lead Poisoning Prevention Program. 2010 Census and 2011 American Community Survey housing and demographic data were incorporated as potential predictors, and the model was fit to 2007-2011 blood lead testing data for children less than six years of age. In an effort to avoid issues of collinearity, stepwise selection was used to determine the final set of predictors.

(ODH, 2016a)

http://www.odh.ohio.gov/~/media/ODH/ASSETS/Files/eh/lead%20poisoning%20-%20children/2014/countyprofiles/richland%20county%202014.pdf

Appendix C



Childhood Lead Poisoning Fact Sheet for the Ashland County/City Health Department

Figure 1. Ashland County Health District. This choropleth map depicts the predicted probability of blood lead levels ≥ 5 µg/dL by census tract. Darker census tracts indicate greater predicted likelihood of children with blood lead levels ≥ 5 µg/dL.

Figure 2. Ashland County Health District and Surrounding Area. This figure characterizes the predicted probability of blood lead levels ≥ 5 µg/dL by census tract. The extent of the Ashland County Health District is outlined in red.

Legend

Predicted Probability of BLLs ≥ 5

<6.8%

6.8% - 11.4%

11.5% - 18.2%

18.3% - 27.3%

>27.3%

All figures depict the predicted proportion of children, less than six years of age, whose blood-lead concentration is equal to or exceeds 5 µg/dL. These estimates were obtained from a lead risk model developed by The Ohio State University Statistical Consulting Service in conjunction with the Ohio Department of Health Healthy Homes and Lead Poisoning Prevention Program. 2010 Census and 2011 American Community Survey housing and demographic data were incorporated as potential predictors, and the model was fit to 2007-2011 blood lead testing data for children less than six years of age. In an effort to avoid issues of collinearity, stepwise selection was used to determine the final set of predictors.

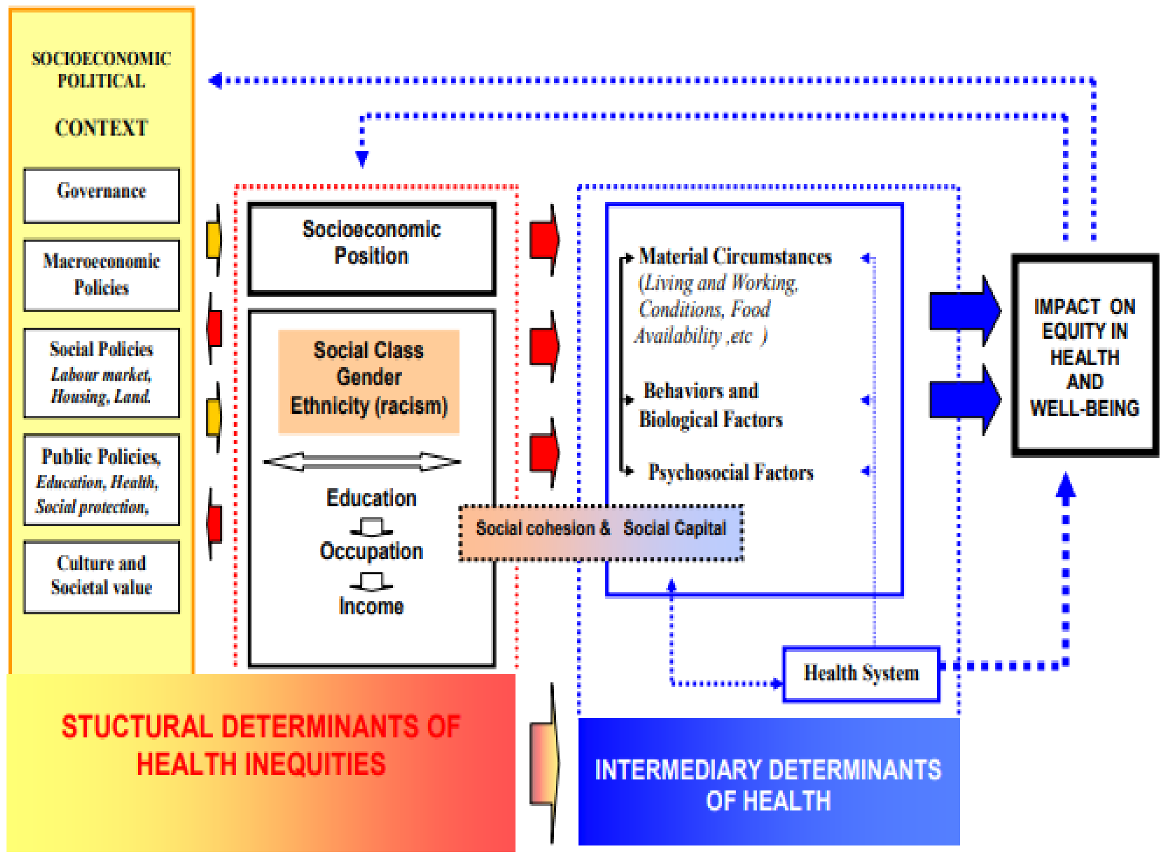
Figure 3. Census Tract 970500: This census tract has the greatest predicted probability of blood lead levels of 5 µg/dL or greater in the Ashland County Health District. The predicted probability of blood lead levels of 5 µg/dL or greater in this census tract is 13.98%.

Ohio Healthy Homes

(ODH, 2016b)

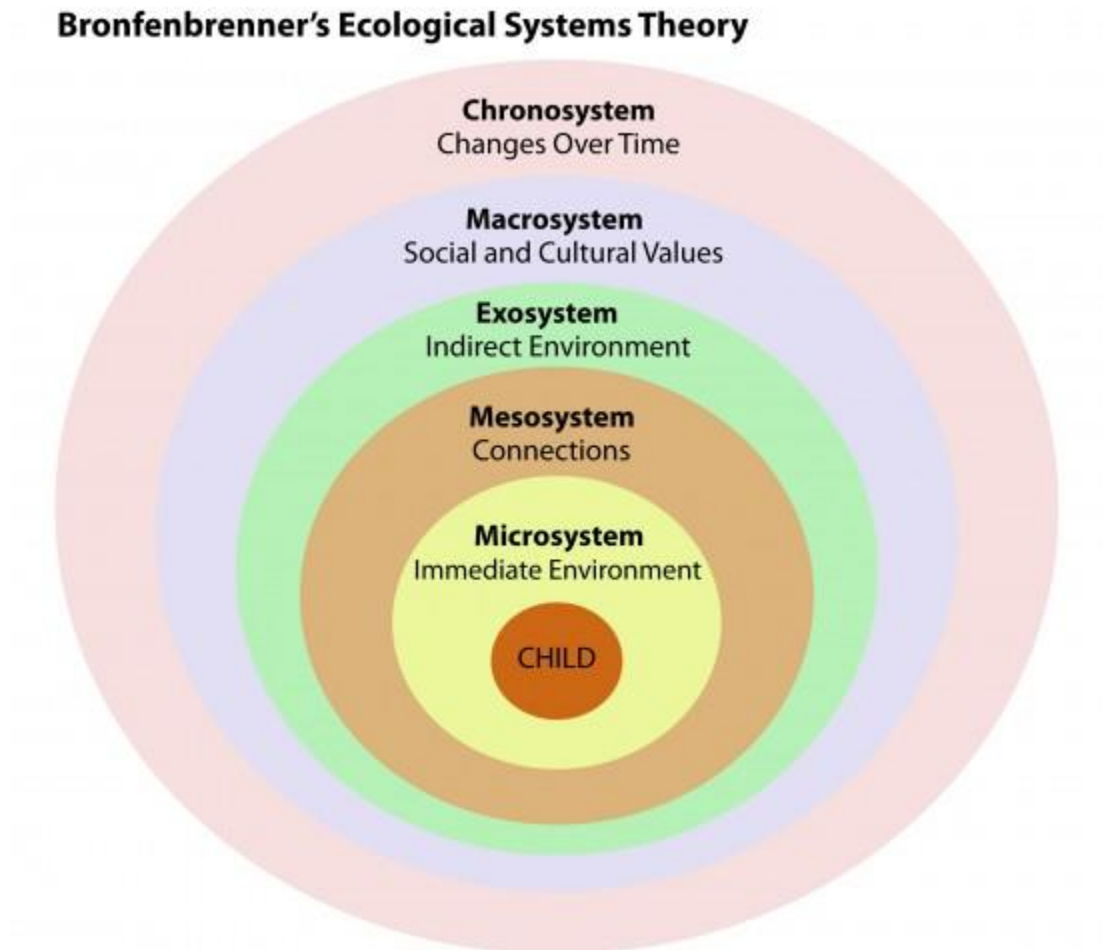
http://www.odh.ohio.gov/~/media/ODH/ASSETS/Files/eh/lead%20poisoning%20-%20children/2014/countyprofiles/ashland%20county%202014.pdf

Appendix D



Social Determinant of Health Framework (WHO, 2010)

Appendix E



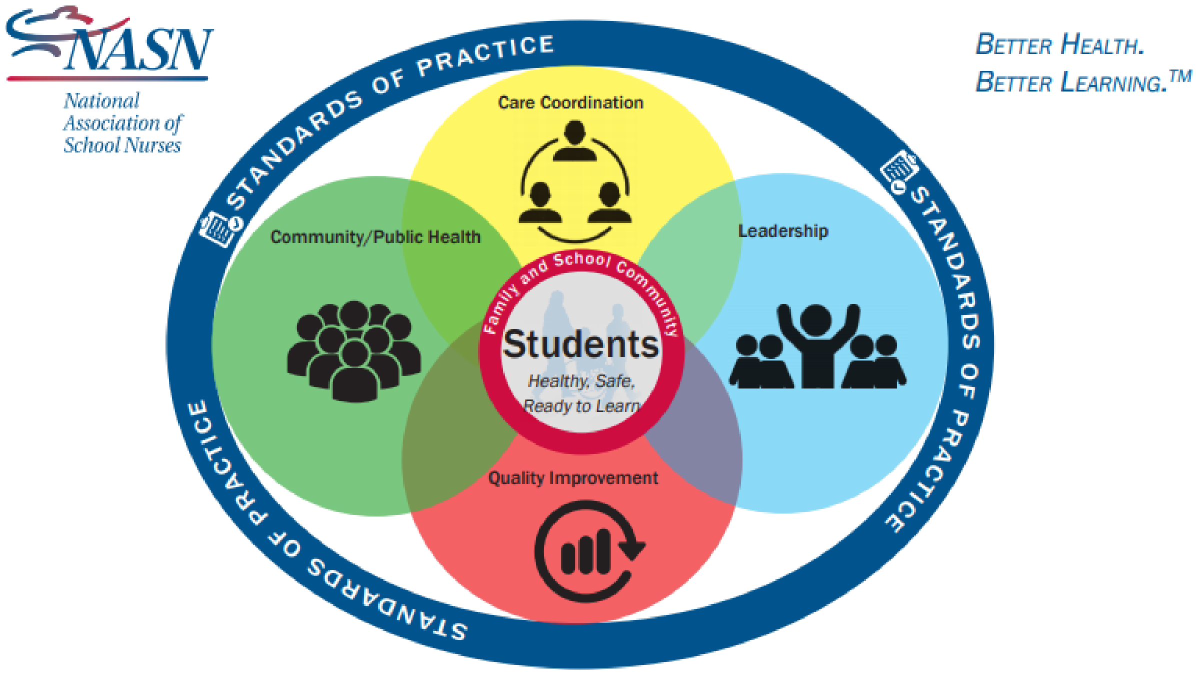
(Psychology Notes, 2013) https://www.psychologynoteshq.com/bronfenbrenner-ecological-theory/

Appendix F

(CDC, 2019) Whole School, Whole Community, Whole Child (WSCC)

Appendix G

Framework for 21st Century School Nursing Practice™



Standards of Practice

- Clinical Competence
- Clinical Guidelines
- Code of Ethics
- Critical Thinking
- Evidence-based Practice
- NASN Position Statements
- Nurse Practice Acts
- Scope and Standards of Practice

Care Coordination

- Case Management
- Chronic Disease Management
- Collaborative Communication
- Direct Care
- Education
- Interdisciplinary Teams
- Motivational Interviewing/ Counseling
- Nursing Delegation
- Student Care Plans
- Student-centered Care
- Student Self-empowerment
- Transition Planning

Leadership

- Advocacy
- Change Agents
- Education Reform
- Funding and Reimbursement
- Healthcare Reform
- Lifelong Learner
- Models of Practice
- Technology
- Policy Development and Implementation
- Professionalism
- Systems-level Leadership

Quality Improvement

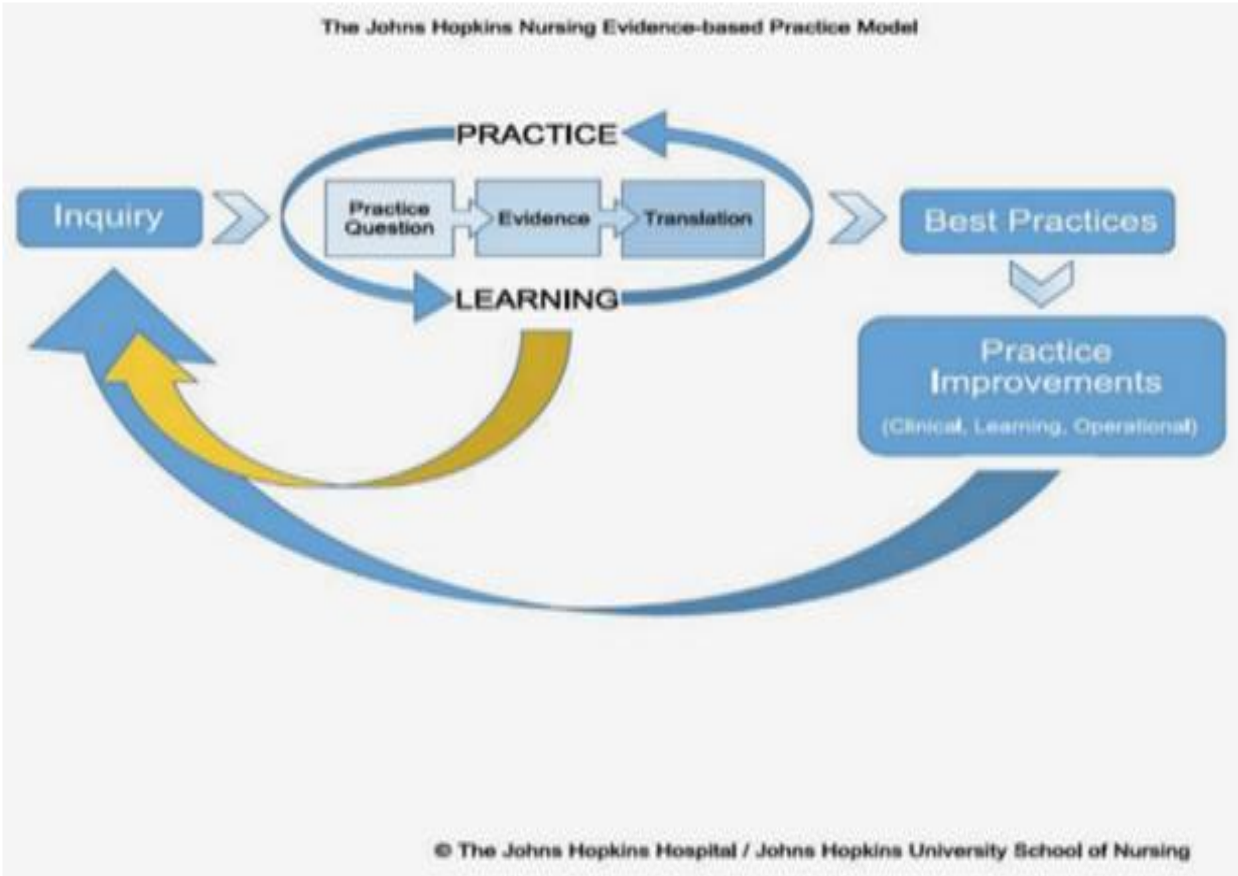
- Continuous Quality Improvement
- Documentation/Data Collection
- Evaluation
- Meaningful Health/ Academic Outcomes
- Performance Appraisal
- Research
- Uniform Data Set

Community/ Public Health

- Access to Care
- Cultural Competency
- Disease Prevention
- Environmental Health
- Health Education
- Health Equity
- Healthy People 2020
- Health Promotion
- Outreach
- Population-based Care
- Risk Reduction
- Screenings/Referral/ Follow-up
- Social Determinants of Health
- Surveillance

(NASN, 2016)

Appendix H

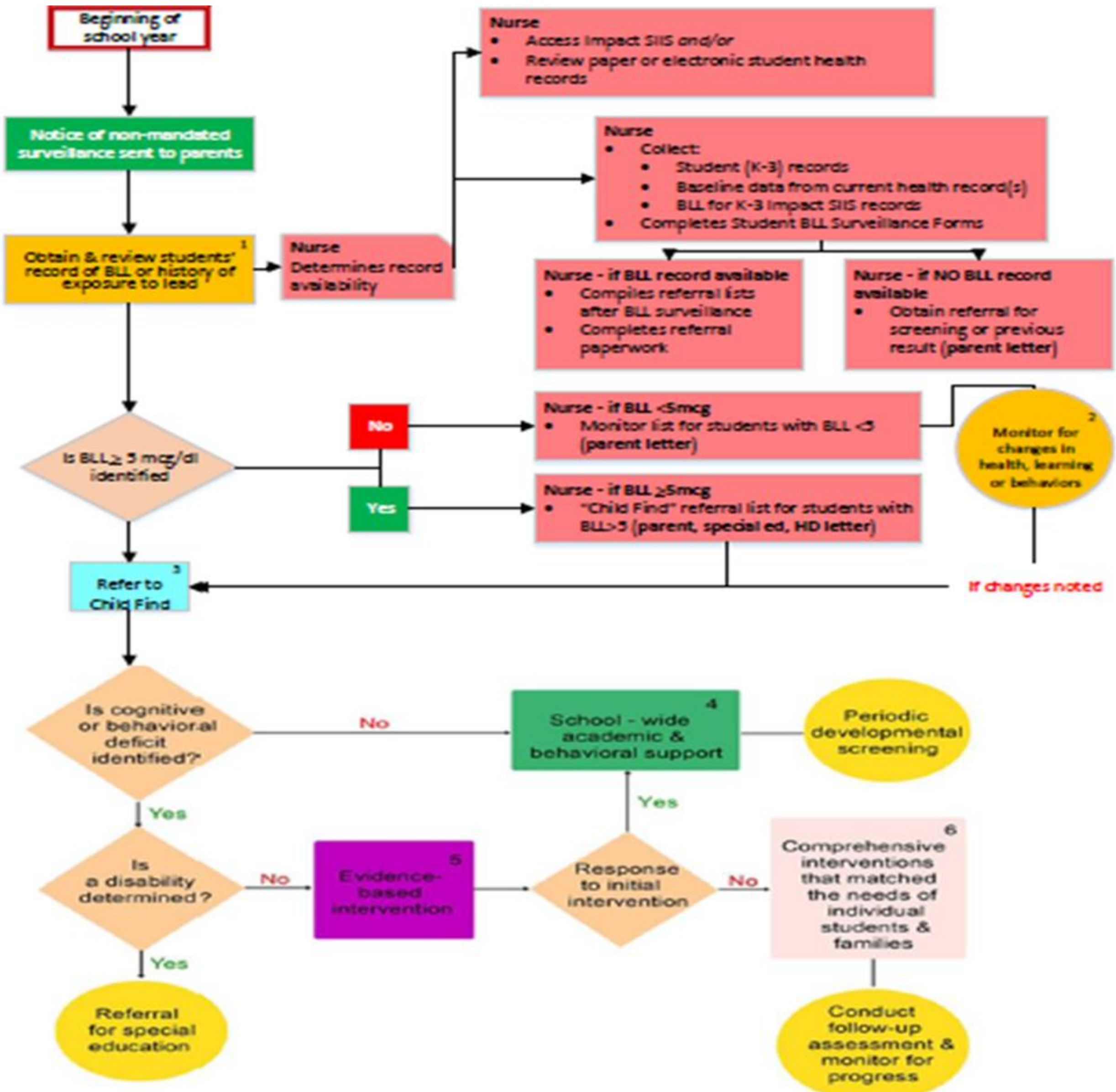


The John Hopkins Nursing Evidence-based Practice Model

(Dang & Dearholt, 2017)

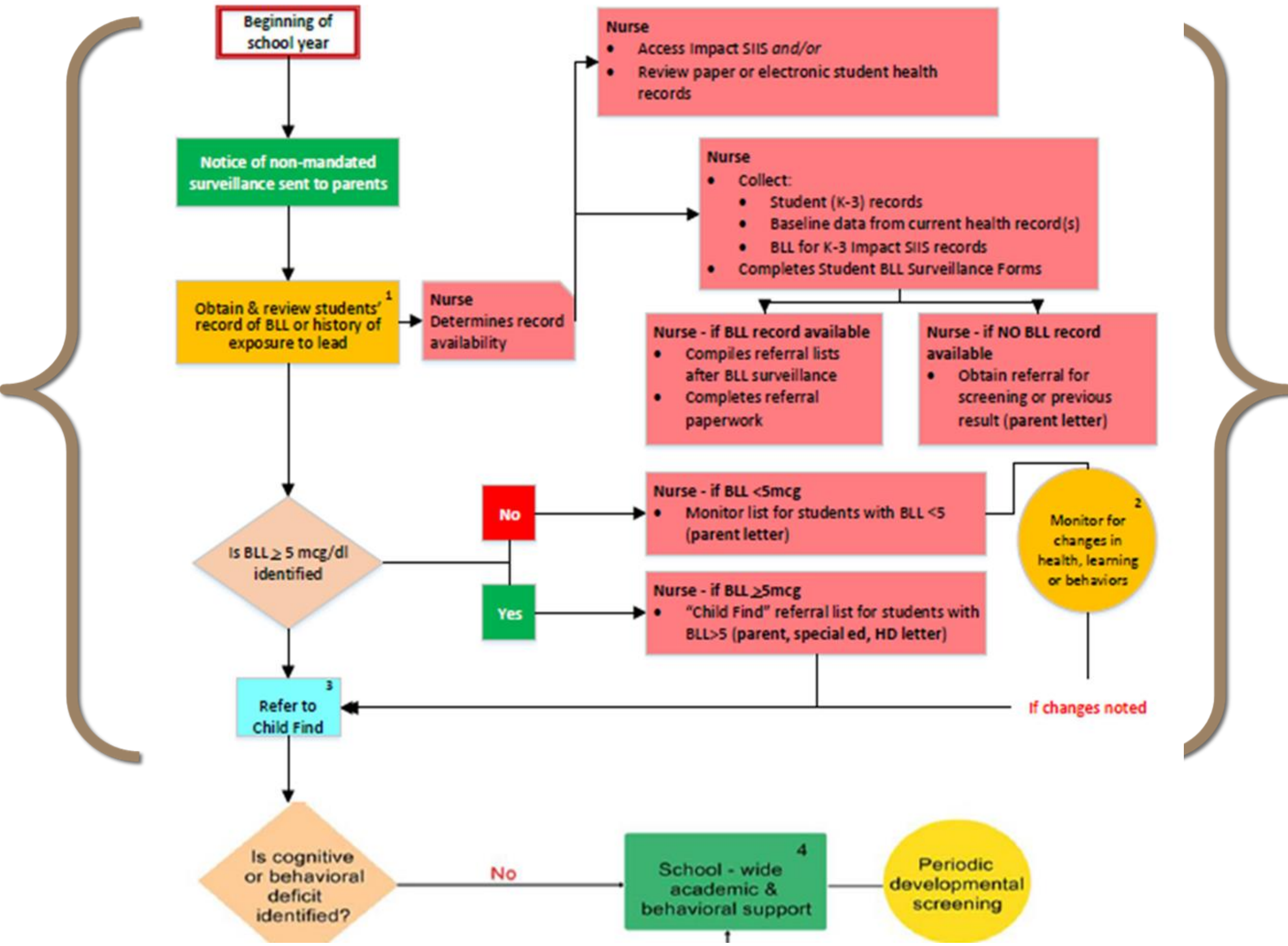
Appendix I

Modified Decision Chart for Ohio School Nurses



Appendix J

Modified Decision Chart for Ohio School Nurses, Scope of Project



Appendix K

Data Collection Forms

Document 1: Student BLL Surveillance Tracking Form Baseline
(For internal school nurse use only)

School: Date:

Student Last Name	Grade	blood lead screening b/t 1-6 yrs		BLL result	source of BLL result		
		Yes	No		PCP HD	Impact SIIS	No record found

School BLL Surveillance Tracking Form—Aggregate Reporting for Project

Document 2: Number of Students Identified from School-based BLL Surveillance Baseline

School: ______________________________________ Date: __________

Grade		K	1	2	3
Total # of students					
Total # of excluded students					
Total # of students with recorded BLL					
blood lead screening b/t 1-6 yrs.	Yes				
	No				
BLL result (# students)					
0-0.9 µg/dL					
1-4.9 µg/dL					
5-9.9 µg/dL					
10-14.9 µg/dL					
15-24.9 µg/dL					
≥25 µg/dL					
Source of BLL result (# students)					
PCP/HD					
Impact SIIS					
No record found					

Document 3: Student BLL Surveillance Tracking Form Post-Implementation

(For internal school nurse use only)

School: Date:

Student Last Name	Grade	blood lead screening b/t 1-6 yrs		BLL result	source of BLL result			History of Health Complaints		History of behavioral referrals		History of intervention services participation		Referral			
		Yes	No		PCP HD	Impact SIIS	No record found	ADHD	Freq. clinic visits	Yes	No	Yes	No	Screening	Monitor	HD	Child find

School BLL Surveillance Tracking Form—Aggregate Reporting for Project

Document 4: Number of Students Identified from School-based BLL Surveillance Post Implementation

School: ____ Date: ___________

Grade		K	1	2	3
Total # of students					
Total # of students with recorded BLL					
blood lead screening b/t 1-6 yrs.	Yes				
	No				
BLL result (# students)					
0-0.9 µg/dL					
1-4.9 µg/dL					
5-9.9 µg/dL					
10-14.9 µg/dL					
15-24.9 µg/dL					
≥25 µg/dL					
Source of BLL result (# students)					
PCP/HD					
Impact SIIS					
No record found					
Type of Referral					
Screening					
Monitor					
HD					
Child find					

Grade: Kindergarten

BLL result (# students)	0-0.9 µg/dL	1-4.9 µg/dL	5-9.9 µg/dL	10-14.9 µg/dL	15-24.9 µg/dL	≥25 µg/dL
Type of Referral						
Screening						
Monitor						
HD						
Child find						
History of Health Complaints						
ADHD						
Freq Clinic Visits						
History of behavioral referrals						
Yes						
No						
History of intervention services participation						
Yes						
No						

Grade: 1

BLL result (# students)	0-0.9 µg/dL	1-4.9 µg/dL	5-9.9 µg/dL	10-14.9 µg/dL	15-24.9 µg/dL	≥25 µg/dL
Type of Referral						
Screening						
Monitor						
HD						
Child find						
History of Health Complaints						
ADHD						
Freq Clinic Visits						
History of behavioral referrals						
Yes						
No						
History of intervention services participation						
Yes						
No						

Grade: 2

BLL result (# students)	0-0.9 µg/dL	1-4.9 µg/dL	5-9.9 µg/dL	10-14.9 µg/dL	15-24.9 µg/dL	>25 µg/dL
Type of Referral						
Screening						
Monitor						
HD						
Child find						
History of Health Complaints						
ADHD						
Freq Clinic Visits						
History of behavioral referrals						
Yes						
No						
History of intervention services participation						
Yes						
No						

Grade: 3

BLL result (# students)	0-0.9 µg/dL	1-4.9 µg/dL	5-9.9 µg/dL	10-14.9 µg/dL	15-24.9 µg/dL	>25 µg/dL
Type of Referral						
Screening						
Monitor						
HD						
Child find						
History of Health Complaints						
ADHD						
Freq Clinic Visits						
History of behavioral referrals						
Yes						
No						
History of intervention services participation						
Yes						
No						

Appendix L

BLL by School, City, and County (ODH, 2017; Dickman, 2017)

<table>
<tr><th></th><th>School A</th><th>Ashland city 2017</th><th>Ashland County 2017</th><th>School B</th><th>Mansfield city 2017</th><th>Richland County 2017</th></tr>
<tr><td>% students 0 µg/dL</td><td>40%</td><td rowspan="3">98.5%</td><td rowspan="3">98%</td><td>0%</td><td rowspan="3">96%</td><td rowspan="3">97%</td></tr>
<tr><td>% students 0.01-0.9 µg/dL</td><td>4%</td><td>0%</td></tr>
<tr><td>% students 1-4.9 µg/dL</td><td>54%</td><td>88.7%</td></tr>
<tr><td>% students 5-9.9 µg/dL</td><td>2%</td><td>1.1%</td><td>1.3%</td><td>8.1%</td><td>2%</td><td>2.6%</td></tr>
<tr><td>% students 10-14.9 µg/dL</td><td>0%</td><td rowspan="3">0.4%</td><td rowspan="3">0.7%</td><td>1.6%</td><td rowspan="3">0.4%</td><td rowspan="3">0.4%</td></tr>
<tr><td>% students 15-24.9 µg/dL</td><td>0%</td><td>1.2%</td></tr>
<tr><td>% students ≥25 µg/dL</td><td>0%</td><td>0.4%</td></tr>
</table>

Appendix M
Critical Appraisal of Evidence

Evidence Table

	Citation	Design/ Methods	Sample/ Setting	Outcome Measurement	Findings	Level of Evidence
1	Amato, M., Moore, C., Magzamen, S., Imm, p., Havlena, J., Anderson, H., & Kanarek, M. 2012	CS	3757 4th grade students Milwaukee WI BLL <5, 10-19 µg/dL	BLL Academic achievement	• BLL↑ • ↓ academic achievement on standardized tests, especially reading and math • BL exposure before age 3 at levels of no intervention show educational disadvantage 7-8 years later	IV High
2	Basch, C 2011	SR		Academic achievement Health disparities Educational disparities Collaboration	• School reform efforts to close the achievement gap have focused on various strategies, yielding very limited progress. • Educationally relevant health disparities influence students' motivation and ability to learn, but reducing these disparities has been largely overlooked as an element of an overall strategy for closing the achievement gap. • If these health problems are not addressed, the educational benefits of other school reform efforts will be jeopardized • Healthier students are better learners. • School health programs and services that are evidence based, strategically planned to influence academic achievement, and effectively coordinated warrant validation as a cohesive school improvement initiative for closing the achievement gap. • National, state, and local responsibilities for supporting school health are outlined • To date, the U.S. Department of Education has not provided leadership for integrating evidence-based, strategically planned,	V High

					and effectively coordinated school health programs and services into the fundamental mission of schools.	
3	Bellinger & Bellinger 2006	SR	40 articles	BLL Public policy Scientific knowledge (level of)	• Historical overview • Scientific knowledge and public policy = need for primary intervention • Evidence presented regarding current practice and evidence-based recommendation for change in policy. Led to 2012-13 CDC policy change • Recommendation of reference value of 97.5% of population screened	V High
4	Bellinger D. (2008a)	LR	Ohio, Cincinnati Lead Study	BLL Neurological effects Behavioral effects	• BLL↑ • Criminal activity↑ in adulthood • ↑ changes in brain structure in adults from childhood exposure • ↓ IQ • Subclinical range of BLL needs to be addressed in larger public health context • Overall BLL decreasing with time	V High
5	Bellinger D. (2008b)	LR		BLL Low level exposure neurodevelopment	• Review of evidence for calls for CDC to reduce screening guideline threshold below 10 µg/dL • BLL↑ • ↑ neuropsychiatric disorders (ADHD, antisocial) • chelation therapy protocols ineffective • No safe level of lead • Low levels associated with neurodevelopmental deficits • Primary prevention is best hope for mitigation	V High

6	Bernard, S. M. & McGeehin, M. A. (2003)	CS	NHANES 88-94 US children age 1-5yr review • Investigation of impact of screening guideline >5 µg/dL vs current 10 µg/dL • Comparison of risk factors among subpopulations	BLL 5-10 µg/dL Socioeconomic factors	• Overall prevalence of BLLs ≥5 µg/dL among 1- to 5-year-old children was 25.6%, although most (76%) of these children had BLLs <10 µg/dL. • Children with BLLs ≥5 µg/dL included 46.8% of non-Hispanic black children, 27.9% of Mexican American children, and 18.7% of non-Hispanic white children • 42.5% of children in housing built before 1946, 38.9% of children in housing built between 1946 and 1973, and 14.1% of children in housing built after 1973 had BLLs ≥5 µg/dL. • Compared with non-Hispanic white children, non-Hispanic black children were 3 times more likely to have a BLL ≥5 but <10 µg/dL, 7 times more likely to have a BLL of 10–20 µg/dL, and 13.5 times more likely to have a BLL ≥20 µg/dL. • BLL↑association with age of housing, region of the country, and poverty	IV High
7	Canfield, R., Henderson, C., Cory-Slechta, D., Cox, C., Jusko, T., & Lanphear, B. (2003)	CS	172 children 6,12,18,24,36,48,60 months BLL Stanford-Binet at ages 3-5 years	BLL<10 µg/dL Intellectual effects Neurobehavioral effects of low levels BLL vs IQ	• BLL↑ • ↓ IQ • each increase of 10 µg/dL in the lifetime average blood lead concentration was associated with a 4.6-point decrease in IQ • IQ declined by 7.4 points as lifetime average blood lead concentrations increased from 1 to 10 µg/dL • Evidence to decreases CDC threshold below 10 µg/dL	IV High
8	Canfield, R., Kreher, D., Cornwell, C., & Henderson, C. (2004)	CS	170 school children Shape School task assessed focused attention, attention switching, working	BLL low level Executive functioning Academic achievement/learning	• BLL↑ • ↓ focused attention, efficiency in naming colors, inhibition of automatic responding, completion of tasks	IV High

			memory, and the ability to inhibit automatic responses		• ↔ performance of difficult tasks requiring attention switching or the combination of inhibition and switching • weak support for impaired executive functioning, but the deficits in color knowledge may indicate a primary sensory deficit or difficulty with forming conditional associations, both implicating disruptions in dopamine system function	
9	CDC, ACCLPP 2012	EO		BLL	• Recommendations for screening reference values need for primary prevention • Update recommendations for reference value every 4 years • Importance of PCP education • PCP monitoring of pt. population >5 • PCP reporting to PHD to provide resources • CDC should promote data sharing between health/housing agencies • Enforcement of preventative policies • CDC should encourage research directed towards interventions maintaining or lowering BLL lower than reference value • Lead exposure with resultant levels above 5 mg/dL has demonstrated effects on IQ, attention span, and academic achievement in children and has established adverse effects on a variety of organ systems (ACCLPP, 2012). • Children younger than 6 years are at the greatest risk for toxicity, and once lead exposure has occurred, it cannot be reversed. • The ACCLPP (2012) also recommends a new focus on the health care provider, with an emphasis on prevention via reduction and elimination of dangerous lead sources instead	V High

					of only responding to elevated blood lead levels (BLLs)	
10	CDC, Educational Services for Children Affected by Lead Expert Panel. (2015).	EO	School-age children	Academic achievement BLL Learning supports	• ↑ BLL • ↓ academic achievement • Primary prevention • Evidence-based supports • Interdisciplinary collaboration • Decision Chart	VII High
11	Cecil, K., Brubaker, C., Adler, C., Dietrich, K., Altave, M., Egelhoff, J.,…., Lanphear, B. (2008)	CS	Children 3-78 months vs Adults >25 yrs with childhood lead exposure Brain volume via MRI Cincinnati Lead Study BLL measured q3mos from birth-5yr then q6 mos to6.5 yrs	BLL Neurological effects	• BLL↑ • ↓ cognition, executive functions, social behaviors, motor abilities • ↓ brain volume (1.2% of gray matter) • most affected regions included frontal gray matter, specifically the anterior cingulate cortex (ACC) responsible for executive functions, mood regulation, and decision-making • Areas of lead-associated gray matter volume loss were much larger and more significant in men than women • fine motor factor scores positively correlated with gray matter volume in the cerebellar hemispheres • blood lead concentration mediates brain volume and fine motor function	IV High
12	Denno, D. (1993).	EO		BLL Behavioral effects Criminal activity	• ↑ BLL • ↑ criminal activity/behavioral impact	VII Medium-Low
13	Dickman, J. (2017).	EO		BLL State policies Screening rates	• Primary prevention • Public policy • Interprofessional collaboration	VII Medium
14	Evens, A., Hryhorczuk, D., Lanphear, B.P., Rankin,		Chicago public school children 58,650	BLL low level Academic achievement	• BLL↑ (but below 10 µg/dL) • ↓ reading and math scores in 3rd grade	IV High

	K.M., Lewis, D.A., Frost, L., & Rosenberg, D. (2015).		• distinct because of the very large sample size and because it controlled for very low birth weight and early preterm birth–two factors closely associated with lower academic performance BLL vs 3rd grade Illinois Standard Achievement Tests (ISAT) reading and math scores	Socioeconomic risk factors	• For a 5 µg/dL increase in BLL, the risk of failing increased by 32% for reading and math • The effect of lead on reading was non-linear with steeper failure rates at lower BLL • 13% of reading failure and 14.8% of math failure attributed to exposure to blood lead concentrations of 5 to 9 vs. 0 to 4 µg/dL in Chicago school children • Preventing lead exposure in early childhood is critical to improving school performance	
15	Fiscella, K., & Kitzman, H. (2009).	LR	NCLB vs HP 2010 goals	BLL Academic achievement Health policy Health disparities Education disparities	• US failing to make significant progress toward the Healthy People 2010 goal of eliminating health disparities • Missing element is a focus on gaps in child development and achievement. Academic achievement and education seem to be critical determinants of health across the life span and disparities in one contribute to disparities in the other • No Child Left Behind Act of 2001 seeks to eliminate gaps in academic child achievement by 2014 • Reforms needed: addressing gaps in child school readiness through adequate investment in child health and early education and reductions in child poverty; closing the gap in child achievement by ensuring equity in school accountability standards; and, importantly, ensuring equity in school funding so that	VII Medium

					resources are allocated on the basis of the needs of the students • ↑ health disparities (race, ethnicity, SES, language, disability)=SDH • ↓ academic achievement	
16	Hu, H. (1991).	CC	35 survivors of lead poisoning from 1930-1944 22 controls for sex, age, town of residence • qualitative	Adult health effects of childhood BLL Long-term consequences of childhood lead poisoning Pregnancy outcomes Intellectual development of resulting children	• ↑ BLL • ↑ spontaneous abortion/stillbirth • ↑ learning disabilities in school age children	IV High
17	Jones, R.L., Homa, D., Meyer, P., Brody, D., Caldwell, K., Pirkle, J. Brown, M. (2009).	CS, LR	US children 1-5 years Data for children aged 1 to 5 years from the National Health and Nutrition Examination Survey III Phase I, 1988–1991, and Phase II, 1991–1994 were compared to data from the survey period 1999–2004	NHANES 88-04 BLL Screening rates	• ↓ prevalence of EBLL >10 decreased from 8.6% in 1988–1991 to 1.4% in 1999–2004, which is an 84% decline • 1988–1991 and 1999–2004, children's geometric mean blood lead levels declined in non-Hispanic black (5.2–2.8 g/dL), Mexican American (3.9–1.9 g/dL), and non-Hispanic white children (3.1 g/dL to 1.7 g/dL) • BLL continue to be highest among non-Hispanic black children relative to Mexican American and non-Hispanic white children • ↑ BLL • ↑ residence in older housing, poverty, age, and being non-Hispanic black • Blood lead testing of Medicaid-enrolled children increased to 41.9% from 19.2% in 1988– 1991 • Only 43.0% of children with elevated blood lead levels had previously been tested	IV High

					• Children's blood lead levels continue to decline in the United States, even in historically high-risk groups for lead poisoning • efforts must continue to test children at high risk for lead poisoning, and identify and control sources of lead • Coordinated prevention strategies at national, state, and local levels will help achieve the goal of elimination of elevated blood lead levels	
18	Lane, S., Webster, N., Levandowski, B., Rubinstein, R., Keefe, R., …Aubry, R. (2008).	CS	Teenage females (15-19 yes) in Syracuse NY • association of childhood lead poisoning with repeat pregnancy and tobacco use among 536 teens who received services at Syracuse Healthy Start between 1998 and 2002	BLL Adolescent/adult health effects	• BLL↑ • ↑ repeat teen pregnancy • ↑ tobacco use • Long-term negative health outcomes associated with childhood lead exposure should not be underestimated • Policy efforts focused on neighborhood development and health education continue to be needed	IV High
19	Lanphear, B. 2005	SR	7 cohort studies International Children: infancy to 5-10 years	BLL IQ	Dosage of lead gradient results BLL↑ IQ ↓	V High
20	Lanphear, B., Dietrich, K., Auinger, P., & Cox, C. (2000).	CS, LR	US 4,853 children ages 6-16 years NHANES 88-94 to assess the relationship between blood lead concentration and performance on tests of arithmetic skills,	IQ BLL<10 µg/dL	• Lead is a confirmed neurotoxin • lowest blood lead concentration associated with deficits in cognitive functioning and academic achievement is poorly defined • geometric mean blood lead concentration for children in the study sample was 1.9; 1 72 (2. 1 %) had blood lead concentrations . 0 • BLL↑	IV High

			reading skills, nonverbal reasoning, and short-term memory		• ↓ cognitive functioning • ↓ math and reading scores for BLL≤5 • For every ug/dL increase in blood lead concentration, there was a 0.7-point decrement in mean arithmetic scores, an approximately -point decrement in mean reading scores, a 0. -point decrement in mean scores on a measure of nonverbal reasoning, and a 0.5-point decrement in mean scores on a measure of short-term memory • Deficits in cognitive and academic skills associated with lead exposure occur at blood lead concentrations lower than 5 ug/dL	
21	Lanphear, B., Hornung, R., Ho, M., Howard, C., Eberle, S., & Knauf, K. (2002).	CS	276 children 6 months of age and followed them until 24 months of age Blood and samples of dust, soil, water and paint were analyzed for lead at 6-month intervals, and interviews were conducted to estimate nutritional, behavioral, and demographic factors linked with lead exposure	BLL Environmental exposures types Health effects Screening rates Primary prevention Nutritional, behavioral, demographical factors	• lead-contaminated floor dust, soil, and water contributed to children's lead intake throughout the first 2 years of life • Lead-contaminated dust from window troughs was a source of lead exposure, especially in the second year of life • BLL↑ • ↓ Dietary iron intake • ↔ Dietary calcium intake • Blood lead concentration was over 50% higher in black than in white children • Black children remain at increased risk for higher blood lead concentration after adjusting for environmental lead exposures and dietary intake	IV High
22	Magzamen, S., Imm, P., Amato, M., Havlena, J., Anderson, H., Moore, C., Kanarek, M. (2013).	CS	Elem students 1133 families association between moderate lead poisoning in early childhood with performance on a	BLL Academic achievement (elem)	• 43% of children were considered exposed • BLL↑ • ↓ lower scores on all sections of WKCE (science, reading, ELA, math, SS) • Children who were black, had a parent with less than a high-school education, and were classified by parents as having less than	IV High

			comprehensive set of end-of-grade examinations at the elementary school level in two urban school districts (WI) 4th grade Wisconsin Knowledge and Concepts Examinations Children were defined as exposed (blood lead level ≥10 and < 20) or not exposed (<5 mg/dL)		excellent health had significantly lower performance on all examination components • ↓ SES, health status=SDH • ↓ lower scores on all sections of WKCE (science, reading, ELA, math, SS)	
23	Marchetti, C. (2003).	LR		BLL Neurodevelopmental effects	• Lead affects the higher functions of the central nervous system and undermines brain growth, preventing the correct development of cognitive and behavioral functions • established neurotoxin/crosses the blood-brain barrier rapidly and concentrates in the brain • Ca dependent proteins and neurotransmitters receptors represent significant targets for Pb • Acute and chronic exposure to lead would predominantly affect two specific protein complexes: protein kinase C and the N-methyl-D-aspartate subtype of glutamate receptor. These protein complexes are deeply involved in learning and cognitive functions and are also thought to interact significantly with each other to mediate these functions	IV High

24	McClaine,P., Navas-Acien, A., Lee, R., Simn, P., Diener-West, M., Agnew, J. (2013)	CS	K students 3406, 59% Hispanic relationship between blood lead levels (BLLs) and reading readiness at kindergarten entry, an early marker of school performance, in a diverse urban school population Providence, RI	BLL Reading IQ Collaboration b/t PH, education, community	• median geometric mean BLL was 4.2 mg/dL • 20% of children had at least 1 venous BLL ≥10 mg/dL • Reading readiness scores decreased by 4.5 and 10.0 points for children with BLLs of 5 to 9 and ≥10 mg/dL, respectively, compared with BLLs <5 mg/dL. • BLLs well below 10 mg/dL were associated with lower reading readiness at kindergarten entry. • The high prevalence of elevated BLLs warrants additional investigation in other high-risk US populations. • Results suggest benefits from additional collaboration between public health, public education, and community data providers • BLL↑ • ↓ reading scores, K readiness	IV High
25	Meyer, P.A., Pivetz, T., Digman, T., Homa, D.M., Schoonover, & J., Brody, D. (2003).		US children state child blood lead surveillance (1-5yrs) data for test results collected during 1997—2001 NHANES 76-00 (<72 mos)	BLL Screening rates	• Lead is neurotoxic and particularly harmful to the developing nervous systems of fetuses and young children • no threshold has been determined regarding lead's harmful effects on children's learning and behavior • HP2000 goal to eliminate BLLs >25 µg/dL by 2000 • a new goal HP2010 targets elimination of BLLs ≥10 µg/dL in children aged <6 years by 2010 • NHANES 1999--2000 survey estimated that 434,000 children or 2.2% of children aged 1--5 years had BLLs ≥10 µg/dL • For 2001, a total of 44 states, the District of Columbia (DC), and New York City (NYC) submitted child blood lead surveillance data to	IV High

					CDC, representing 95% of the U.S. population of children aged <72 months and 97% of the nation's pre-1950 housing • number of children tested and reported to CDC increased from 1,703,356 in 1997 (37 states, DC, and NYC reporting), to 2,422,298 in 2001 (44 states, DC, and NYC reporting) • Number of children reported with confirmed elevated BLLs $\geq$10 µg/dL steadily decreased from 130,512 in 1997 to 74,887 in 2001. • In 2000, the year targeted for national elimination of BLLs >25 µg/dL, 8,723 children had BLLs $\geq$25 µg/dL. • Both national surveys and state surveillance data indicate children's BLLs continue to decline throughout the United States. • Thousands of children continue to be identified with elevated BLLs. • The 2000 goal of eliminating BLLs >25 µg/dL was not met. (HP2000) • Attaining the 2010 goal of eliminating BLLs $\geq$10 µg/dL will require intensified efforts to target areas at highest risk, evaluate preventive measures, and improve the quality of surveillance data. HP2010. • Public Health Actions: • States will continue to use surveillance data to 1) promote legislation supporting lead poisoning prevention activities, 2) obtain funding, 3) identify risk groups, 4) target and evaluate prevention activities, and 5) monitor and describe progress toward elimination of BLLs $\geq$10 µg/dL. • CDC will work with state and local programs to improve tracking systems and the collection, timeliness, and quality of surveillance data.	

26	Miranda, M., Kim, D., Reiter, J., Overstreet-Galeano, M., & Maxson, P. (2009).	CS	North Carolina Childhood Lead Poisoning Prevention Program surveillance registry were linked to educational outcomes available through the North Carolina Education Research Data Center for all 100 counties in NC	BLL Academic achievement Screening rates	• ↓academic achievement • ↓ SES, blacks, disadvantaged groups, parental educational attainment, family poverty status • ↑ cumulative childhood social and environmental stress=SDH • The effects of environmental and social stressors demonstrate the particular vulnerabilities of socioeconomically and environmentally disadvantaged children. • Given the higher average lead exposure experienced by African American children in the United States, lead does in fact explain part of the achievement gap	IV High
27	Muenning 2009	CS	All children birth-6yr in 2008 NHANES data	BLL IQ Earnings Crime costs Welfare costs Health benefits Prospective look	↑ BLL ↓IQ ↓ earnings ↑ criminal justice costs, behaviors ↑ SDH impact ↑healthcare costs More aggressive programs aimed at reducing childhood lead exposure may produce large social benefits	IV Medium
28	National Toxicology Program (NTP). (2012).	SR		BLL Child health effects Adult health effects	• Long-term health impacts • Long-term behavioral impacts • Generation to generation health impacts	V High
29	Needleman, H. & Gatsonis, C. (1990).	SR	24 modern studies of childhood exposures to lead in relation to IQ, 12 that employed multiple regression analysis with IQ as the dependent variable and lead as the main effect and that	BLL low level IQ	• hypothesis that lead impairs children's IQ at low dose is strongly supported • The effect is robust to the impact of any single study	IV High

			controlled for nonlead covariates were selected for a quantitative, integrated review or meta-analysis			
30	Needleman, H. (2002).	C C	194 youths 12-18 yrs arrested and adjudicated as delinquent by the Juvenile Court of Allegheny County, PA and 146 nondelinquent controls from high schools in the city of Pittsburgh	Bone lead Delinquent behavior	• ↑ bone lead • ↑ arrested or adjudicated, black and white • adjudicated delinquents were four times more likely to have bone lead concentrations > 25 ppm than controls • Elevated body lead burdens, measured by bone lead concentrations, are associated with elevated risk for adjudicated delinquency	IV High
31	Needleman, H., Riess, J., Tobin, M., Biesecker, G., & Greenhouse, J. (1996).	CS	Public school 850 boys in the first grade at public schools, 503 were selected on the basis of a risk scale for antisocial behavior Child Behavior Checklist (CBCL)	BLL Bone lead Delinquent behavior, social adjustment	• ↑ bone lead • ↑ teacher reports of student somatic complaints, anxiety/depression, social behaviors, attention problems, delinquent, aggressive, internalizing, and externalizing behaviors • ↑ student reports of delinquency • ↓ CBCL scores • ↑ risk for exceeding clinical score for attention, aggression, delinquency	IV High
32	Needleman, H.L., Gunnoe, C., Leviton, A., Reed, R., Peresie, H., Maher, C., & Barrett, P. (1979).	CS	58 children with high and 100 with low dentine lead level s was compared WISC 2146 children by teachers' questionnaire on behavior	Dentine lead IQ Psych/behavioral effects Academic achievement	• ↑ dentine lead • ↓ WISC scores (verbal subtests, measures of auditory/speech processing, attention) • ↑ non-adaptive classroom behaviors • Lead exposure, at doses below those producing symptoms severe enough to be diagnosed clinically, appears to be associated with neuropsychological deficits that may interfere with classroom performance	IV High

					• Lead exposure is associated with increased risk for antisocial and delinquent behavior, and the effect follows a developmental course	
33	Ness, R. (2013).	LR	Review of ACCLPP 2012	BLL Primary prevention Primary care Practice guidelines	• About 3 million children are screened annually for lead exposure and toxicity; about 250,000 children are found to have BLLs > 10 mg/dL, and an additional 200,000 are found to have BLLs between 5 mg/dL and 10 mg/dL • Lead exposure can begin in utero (ACCLPP, 2012). The following groups should be screened for lead exposure immediately: all children at the recommended screening ages, immigrants, refugees, and children born or adopted outside the United States (ACCLPP, 2012). Although pregnant women are not routinely screened, the CDC recommends that pregnant women, mothers who are breast-feeding, and newborns be screened if they are living in a home that has been identified with an elevated lead level (CDC, 2012b). Children presenting with hand-to-mouth behavior beyond the normal age range should be considered at increased risk for lead exposure (ACCLPP, 2012) • Environmental assessment questions should not replace recommended screening of blood levels at the recommended ages. • Signs and symptoms (Box 2) can be difficult to detect in children who have chronic low-level exposure and often present with no obvious clinical signs (Burns et al., 2009). • Coordination with local childhood lead poisoning prevention programs within the community is necessary to help determine the source of the lead and have it removed	VII Medium

34	Nevin, R. (2000).	SR	US children CogAT scores 1984-1992	BLL IQ Crime rates Unwed pregnancy	• ↑ BLL • ↓ CogAT/IQ • ↑Violent crime • ↑unwed pregnancies	IV High
35	Pell, M. & Schneyer, J. (2016, June 9).	LR		BLL Screening rates	• ↓ BLL screening rates • Primary prevention • Public policy	VII Medium
36	Pew Charitable Trust & RWJF. (2017).	SR		Practice guidelines Public policy Costs	• Primary prevention • ↑ BLL • ↑ healthcare, criminal justice, educational costs • Interdisciplinary collaboration	VII Medium
37	Raymond, J. & Brown, M. (2017).	CS	US children 1-5 years NHANES 09-14 CDC examined BLLs of children aged <5 years in three categories: children with BLLs ≥10 μg/dL, children with new reports of BLLs ≥10 μg/dL, and children with BLLs 5–9 μg/dL.	BLL Screening rates Historical overview	• No safe BLLs in children have been identified • Permanent neurologic damage and behavioral disorders are associated with BLLs at or below 5 μg/dL • 2012, a total of 30 jurisdictions (28 states, the District of Columbia, and New York City) identified and reported approximately 138,000 children aged <6 years with BLLs ≥5 μg/dL • Federal funding ended in 2012, and several states lost their statewide lead programs. As a result, by 2013, the number of children reported to CDC with BLLs ≥5μg/dL decreased, as did the number of states reporting • When federal funding returned in 2014, a total of 35 programs were funded through CDC • reporting criteria of BLLs from the laboratories to the state are set by each state and vary across jurisdictions • Elevated BLLs have been a notifiable condition since 1995 CDC asks state and local health departments to report all blood lead test data for children to HHLPPP, regardless of the BLL • ↑BLL • ↑neurological damage, permanent	IV High

					• ↑behavioral disorders BLL<5 • ↑ exposure from lead paint • one study has shown that capillary blood draws are suitable alternatives to venous blood draws when screening children aged <6 years to determine lead exposure and provide reasonable estimates at the population level • Effective surveillance requires state and local health departments to track a substantial number of children and their blood lead test results over time	
38	Raymond, J., Wheeler, W., & Brown, M. (2014).	CS	US children 1-2 years NHANES 99-10	BLL Screening rates	• ↓ BLL screening rates	IV High

39	Wengrovitz, A.M. & Brown, M.J. (2009).	LR	US Medicaid children 1-5 years	BLL Medicaid Targeted screening Screening rates	• Lead is a potent, pervasive neurotoxin, and elevated blood lead levels (EBLLs) can result in decreased IQ, academic failure, and behavioral problems in children • Eliminating EBLLs among children is one of the 2010 U.S. national health objectives HP2010, To meet this objective, the limited available resources must be focused on the populations at highest risk for EBLLs • Rather than provide universal screening to all Medicaid children, which was previously recommended, state and local officials should target screening toward specific groups of children in their area at higher risk for EBLLs • During 1999--2004, 1.4% of children in the United States aged 1--5 years had elevated blood lead levels (EBLLs), compared with 8.6% of children during 1988—1991 • Data from NHANES indicate that during 1976--2004, a substantial decrease occurred in the percentage of young children aged 1--5 years with EBLLs (77.8% during 1976--1980, 4.4% during 1991--1994, and 1.4% during 1999--2004) • BLLs have decreased among all age and ethnic groups • NHANES data indicate that disparities continue to exist in mean BLL by race, income level, age of residence, and other available risk factors. • State and local data have gradually become more important than national data for developing lead exposure prevention policies at the state and local level. • These studies are consistent with programmatic experience and suggest that children in low-income families served by Medicaid and WIC have experienced a decrease in BLLs similar to	V High

					the decrease in the general population. In addition, the disparity in risk for lead exposure between Medicaid-eligible children and non-Medicaid-eligible children might be decreasing. These results indicate that children who are eligible for Medicaid can no longer be assumed to have an increased risk for EBLLs. Thus, rather than a single national policy that is used for all Medicaid children, a new blood lead screening strategy is needed that accounts for local variations in risk and disparities at the local level. • The primary purpose of childhood blood lead screening has been to identify asymptomatic children with EBLLs so that they can promptly receive services to reduce lead exposure and improve health outcomes • Collaborations, increased data sharing, partnerships with WIC, motivate HCP, reduce barriers to screening	

40	White, B., Shaw-Bonilha, H., Ellllis, C. (2016)	SR	US children <72 months examined racial/ethnic differences in blood lead levels among children under 6 years of age PubMed, CINAHL, and PsycINFO databases for published works from 2002 to 2012	BLL Racial/ethnic disparities Screening rates	• Childhood lead poisoning is a serious public health problem with long-term adverse effects • Healthy People 2020's environmental health objective aims to reduce childhood blood lead levels; however, efforts may be hindered by potential racial/ethnic differences • ↑ BLL • ↑ black	V High
41	Yule, W., Lansdown, R., Millar, I., & Urbanowicz, M. (1981).	CS	166 US children	BLL IQ Academic achievement	• ↑ BLL • ↓ reading, spelling, IQ • ↔ math • ↔SES	IV Medium
42	Zhang, N., Baker, H., Tufts, M., Raymond, R., Salihu, H., & Elliott, M. (2013).	CS	Detroit Public Schools AA students Elementary Junior high	BLL Academic achievement	• Early childhood exposure • Long-term academic impact • Controlled for demographics, SES • 1st study of direct academic impact	IV Medium

Legend example: EO=Expert Opinion; D=depression; Q=quasi-experimental design; RCT=randomized controlled trial; CC=case control;

CS=cohort study; LR=literature review; SR=systematic review ↑ = increased; ↓ = decreased; ↔ = no effect

Synthesis Table

References	Recommendations/Outcomes							
	Primary prevention	Interdisciplinary efforts	IQ impact	Academic impact	Public policy	low level exposure (subclinical)	Behavioral impact	Long-term health effects	Linked to SDH
1				X					
2		X		X	X				X
3	X	X			X	X			
4			X			X	X	X	
5	X					X	X	X	
6						X			X
7			X			X			
8				X		X	X		
9	X	X	X	X	X	X	X	X	X
10	X	X	X	X	X	X	X	X	X
11			X	X			X	X	
12							X		
13	X				X				
14	X			X		X			
15	X	X		X	X				X
16					X			X	
17	X	X			X	X			X
18		X			X		X	X	
19			X						
20			X	X					
21						X	X		X
22				X					X
23							X		
24	X	X		X					
25	X	X			X	X		X	
26	X	X							X
27				X					X
28			X			X	X	X	X
29			X				X	X	
30			X			X			
31				X			X		
32				X			X	X	
33	X	X		X	X	X	X	X	
34			X				X	X	
35	X	X				X			X
36	X	X			X	X	X	X	X
37	X	X			X	X	X	X	
38	X				X	X			
39	X	X	X	X	X	X	X	X	X
40	X				X	X			X
41			X	X					
42				X		X			X